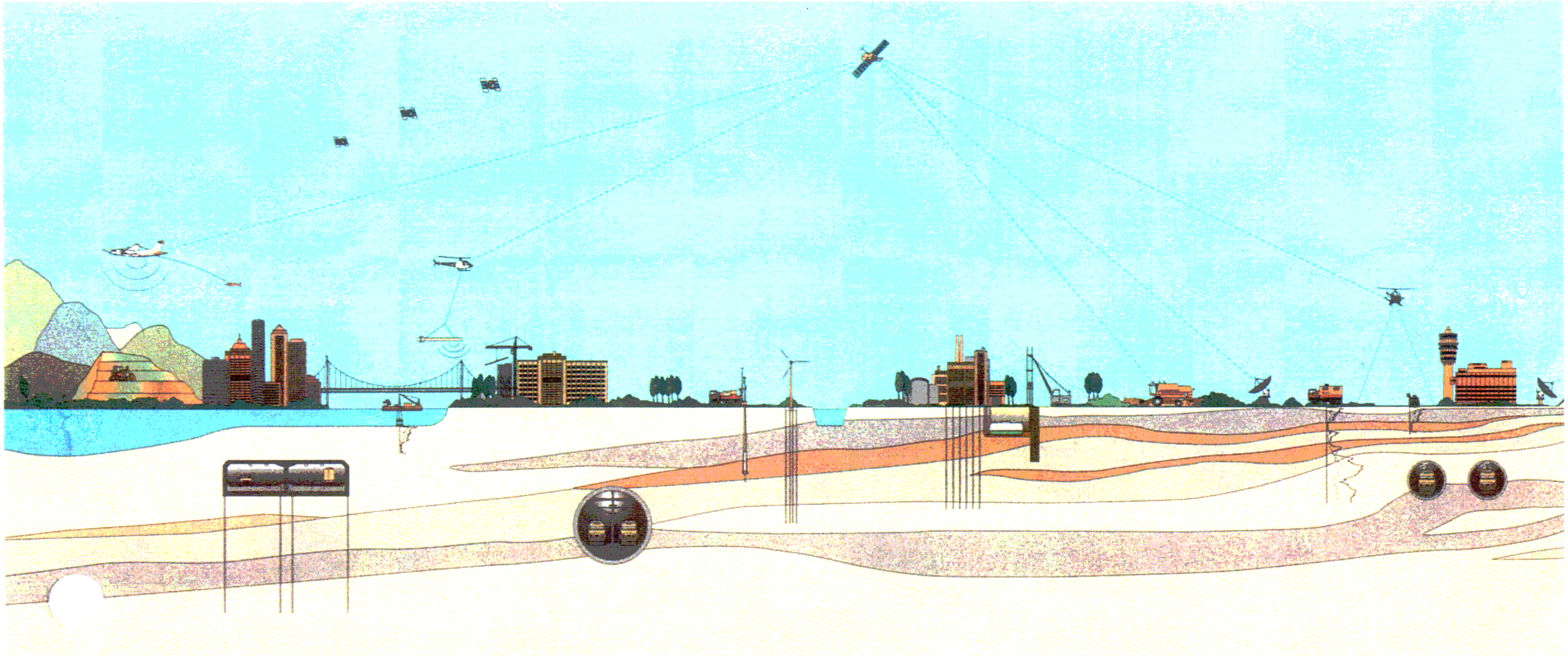
JOHN CHANCE LAND SURVEYS, INC.

FLI-MAP
JOHN CHANCE LAND SURVEYS

U.S. ARMY CORPS OF ENGINEERS
ST. LOUIS DISTRICT
GRAND CANYON MONITORING & RESEARCH CENTER

SURVEY CONTROL REPORT
Grand Canyon, Arizona
LIDAR Survey for the South Canyon & Eminence Sites
Contract No. DACW43-02-D-0505
JCLS Job #03-6027
May 2003



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1.0 FLI-MAP® SYSTEM DESCRIPTION

1.1 FLI-MAP®

The following is a brief description of how FLI-MAP® integrates the use of LiDAR technology and GPS to meet the challenge for a fast and accurate means of aerial surveying. The mobile FLI-MAP® system was designed by John E Chance & Associates. The system description will be for the mobile FLI-MAP® system, which can be attached to several types of helicopters.

1.1.1 System description FLI-MAP®

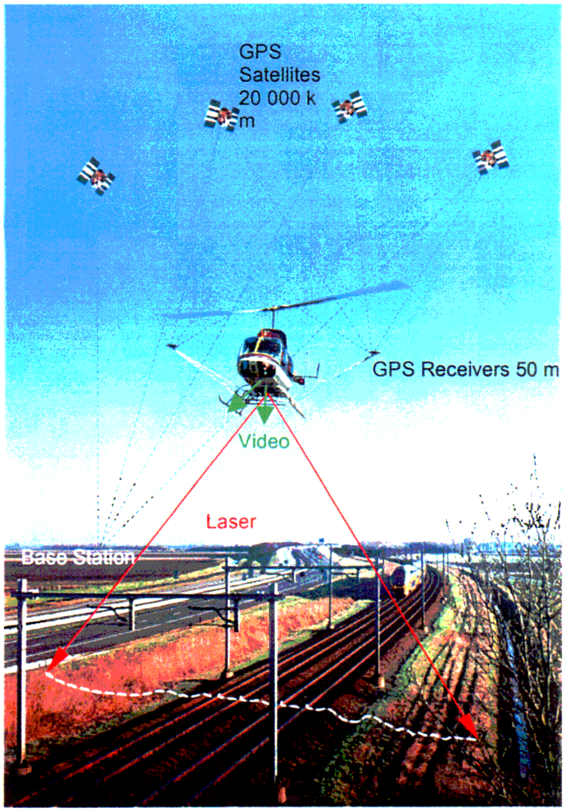

Figure 1: FLI-MAP® system

The basic concept is that a helicopter flies over the corridor to be surveyed, collecting precise GPS measurements, platform attitude, laser ranges, and imagery data.

The LiDAR sensor scans the terrain and objects directly below the helicopter at a rate of 10 000 points a second. The scan width is 1.15 times the helicopter height above the ground. The terrain directly below and forward of the aircraft is imaged with high-resolution video cameras, and recorded with a digital time stamp. Figure 1 is a graphical presentation of the FLI-MAP® system.

The final post processed output, including the video from the FLI-MAP system, includes XYZ positions of the laser returns. The data density that is required to differentiate railway infrastructure components such as rails, mile posts, signals, switches, electrification wires, masts, etc. is at least 10 points per m^2. These railway infrastructure components are identified by patterns of points with spatial relationships. Thus, the FLI-MAP® system integrates several main systems into a high-tech survey tool and the various subsystems are described below:

Positioning System

FLI-MAP® incorporates two rover (moving) GPS receivers (dual frequency L1/L2) and multiple ground reference GPS receivers. These GPS receivers, both moving and ground reference, record the dual frequency carrier phase and pseudo range measurements from each satellite. The two airborne moving receivers (with separate antennas) provide a redundancy check on the post-processed kinematic DGPS aircraft position. Figure 2 shows the two moving GPS receivers mounted on the helicopter.

Figure 2: Moving GPS Receivers

Navigation System

Omnistar® satellite receivers are used to collect standard RTCM-104 differential corrections, which provide a sub-meter accuracy of the helicopter for real-time pilot navigation. A higher level of accuracy and reliability of the position (< 10cm) can be calculated during post processing.

Attitude System

A solid state Inertial Measurement Unit (IMU) is used to measure instantaneous pitch, roll and heading, as well as accelerations of the platform in three dimensions. These measurements are used by the integrated Inertial Navigation System (INS) to calculate accurate attitude of the helicopter at every sampling location. The INS also provides redundancy checks on the aircraft position during the post processing.

Laser System

The scanning laser is a custom designed eye safe, reflectorless rangefinder using near middle Infrared light and is capable of measuring first return ranges from 20 - 250 meters. The laser light is generally reflected omni-directionally from an uncooperative target according to Lambert's cosine law, see Figure 3.

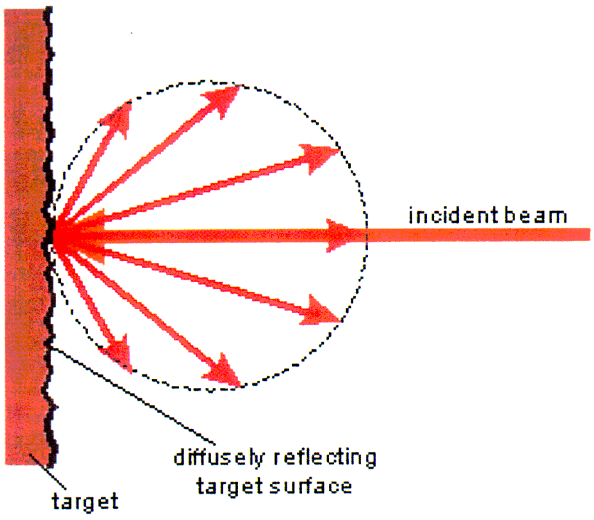

Figure 3: Uncooperative Target Reflection

The reflectivity of typical materials encountered is given in Table 1

Table 1: Material Reflectivity

MATERIAL	REFLECTIVITY
White paper	up to 100%
Snow	80-90%
Limestone, clay	up to 75%
Deciduous trees	typ. 60%
Coniferous trees	typ. 30%
Carbonate sand	57 - 41%
Beach sands	typ. 50%
Concrete, smooth	24%
Asphalt with pebbles	17%
Lava	8%
Black neoprene	5%
Black rubber tire wall	2%
(Values shown for 900 nm wavelength)	

Every scan contains 200 distance measurements and has a width of 60 degrees. Each scan record also contains referencing, timing, laser attitude, data verification/error detection information and intensity information which provides an active infrared imaging capability. Operationally, the laser scans at a rate of 50 times per second, which results in 10 000 points per second.

Video System

FLI-MAP is equipped with two high resolution, broadcast quality, color video cameras, producing 750 horizontal TV lines with the 3-chip CCD. The video data is recorded directly to hard drives in MPEG format. The down looking camera records approximately the same area that is laser scanned and has a zoom factor of approximately x1. The forward-looking camera, mounted in an oblique position, has a fixed focal length with a zoom factor of approximately x1.5. The precise UTC time is encoded on each frame of video, allowing for accurate correlation with the laser data. All pilot / operator communications and voice notes are recorded on the audio track of the MPEG recorder for archiving and aiding in image interpretation.

Digital Still System

FLI-MAP is also equipped with two digital, ½" CCD, high-resolution still cameras set in the down and forward-looking perspectives. Both cameras incorporate an IEEE 1394, Firewire interface, capturing 1 frame per second per camera. The down looking camera has a zoom factor of x1 and the forward-looking camera has a zoom factor of approximately x1.5. At a typical flight altitude of 50 meters, the down looking camera delivers images with a resolution of approximately 4 centimeters per pixel.

Display and Acquisition System

The FLI-MAP® system can direct and guide the pilot along predetermined survey flight lines, using LED light bars to indicate course deviation, both horizontally and vertically. The horizontal course is determined by the navigation and positioning systems and the scanning laser Average Ground Level (AGL) feature provides the vertical course. The pilot and operator can view both the down-looking and forward-looking video on a flat screen color display, while the operator has a dedicated laptop for control and status monitoring of the system during operations.

The airborne processing system is a multiple Intel-based PC, which provides airborne data management, sensor control, and navigation processing. The measurements such as GPS pseudo ranges and carrier phase, laser scan records, and the real-time differential and INS solutions, are stored on removable memory cards.

Aircraft Integration

As the FLI-MAP® system is a modular design, it can be mounted to various types of helicopters. For this purpose the system is divided into two main parts, the sensor platform and the Electronic Control Unit (ECU). The sensor platform is mounted to standard cargo connection points below the helicopter. This platform contains the laser, IMU and video cameras and two specially designed extensions on which the GPS antennas are mounted. The ECU contains all the necessary data collecting and processing equipment such as GPS and Omnistar receivers, the INS, video recorders, computer board and data storage facilities. The box (19 in.) is fixed inside the helicopter and is connected to the sensor platform by means of an 'umbilical cord'. Figure 4 shows the sensor platform and the ECU.

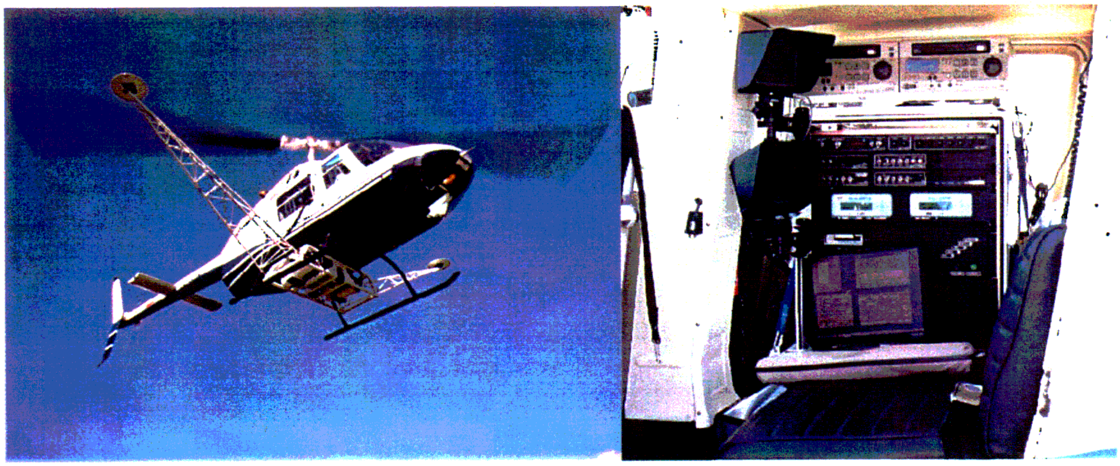

Figure 4: Helicopter with Mobile Sensor Platform and EMU Onboard

2.0 PROJECT DESCRIPTION

2.1 Project Description

In May 2003, John Chance Land Surveys, Inc. was contracted to St. Louis District Corps of Engineers for acquiring digital elevation data along two projects in northern Arizona for the Grand Canyon Monitoring & Research Center & USGS utilizing the FLI-MAP® LIDAR system. The two projects are the Eminence and South Canyon areas.

The purpose for the surveys is to obtain a precise survey and develop a digital terrain model (DTM) of the projects to be surveyed for the purpose of determining volumes or obtaining other engineering data. The survey will be accomplished utilizing aerial topographic laser surveying techniques (LIDAR) to develop and identify all right of way characteristics and develop digital terrain models as necessary to obtain profiles of road crossing, piers, and other physical features.

The deliverables for this project consist of the following:

a. A survey narrative shall be produced in the form of a letter type report detailing all aspects of the LIDAR flight, including a description of the fieldwork and detailed office data processing procedures. The description shall include location, navigation and control, operations, all survey logs and data sheets used, any difficulties with the survey, and the method of resolution of the difficulties shall be documented. Two copies of the report for each of the two projects shall be provided.

b. The contractor shall provide an interpretation and analysis of the results of the survey, including data quality, coverage of the area, and a summary of the findings. This summary shall be included in the transmittal letter documenting the electronic data delivered as a result of the survey. Two copies of each project shall be provided.

c. Fli-Map laser data will be delivered on DVD with the latest version of the FLIP-7 software. Upgrades to FLIP-7 software may be necessary for current users. Also, high-resolution color digital video imagery (360 x 240 pixels) that is time coded to the Fli-Map data will be delivered of the entire route in mpeg format. Three videos should be submitted including forward and down perspective with the third video being a digitized double zoom down video. Two copies of the Fli-Map laser data and digital video imagery shall be submitted on DVD. Additionally, two copies of ASCII data for the entire project shall be submitted on CD-ROM for use within other software that may not read the FLIP7 compressed data format.

d. Two copies of two data sets are required. Both a cleaned and edited raw Fli-Map data set and a thinned to approximately 5% data set shall be delivered in ASCII format. The entire data set shall be filtered to produce a bare earth model and delivered in ASCII format. ASCII data file size shall be no greater than 200,000 points. Both a hard copy and digital index of the data file shall be produced.

e. The contractor will provide up to 24 hours of training for up to six engineers or technicians or their representatives in the use of FLIP7 software. The training will be conducted at the Contractors office location. Transportation costs and per diem costs will be paid by government personnel attending the training. FLIP7 technical support shall be provided for 24 hours of help (for each engineer or technician) by telephone over a one-year period. Responses to requests for technical support shall be made during normal business hours within 2 business days of initial inquiry. New releases or upgrades of the FLIP7 software shall be provided to the St. Louis District of the U.S. Arm Corps of Engineers and the GCMRC, Flagstaff, AZ at no cost of the government for a period of one year.

f. A metadata file at least minimally compliant with the Federal Geographic Data Committee (FGDC) Content Standards for Digital Geospatial Metadata. The COE will provide a Metadata generation package (CORPSMET) to generate these files upon request by the Contractor or the Contractor can use software of their choice as long as the FGDC compliant Metadata is produced as specified in 2.b above.

3.0 DATA COLLECITON SUMMARY

3.1 Data Collection Summary

The following are daily reports of the field activities during job reconnaissance and data collection. Further detailed information about the data collection flights can be found in section 5.5 "Flight Information".

Friday, May 23, 2003: Five employees of John Chance Land Surveys, Inc., Connie Landry, Chris Guillory, Faron Olivier, Terry Richard, and Steve Broussard arrived in Tusayan,AZ.

Saturday, May 24, 2003: Connie, Chris, Faron, Terry, and Steve located all of the control for the two projects. Blaine Thibodeaux and Morgan Reed arrived by plane.

Sunday, May 25, 2003: Crew performed the static survey for the both projects. The FLI-MAP system was installed on the helicopter and a test flight was performed.

Monday, May 26, 2003: The first day of data collection consisted of two flights. The first flight consisted of data collection for the South Canyon Site. It consisted of approximately 20.8 miles of data collection during a 1 hr 34 min flight. The second flight consisted of approximately 24 miles of data collection for the Eminence Site during a 1 hr 32 min flight. The base stations used for these flights were "EMIN", "SCTH", & "BCTH". The laser data was processed, verified for coverage and transferred onto CD-ROM. The digital video & Imagery was verified and transferred onto DVD. All data was collected at an approximate altitude of 100 meters with an average ground speed of 17 meters per second.

Tuesday, May 27, 2003: The second data of data collection consisted of one flight. The 1 hr 28 min flight consisted of approximately 19.74 miles of data collection for the Eminence Site. The Eminence Site was recollected due to GPS gaps from the previous day. The base stations used for these flights were "EMIN", "SCTH", & "BCTH". The laser data was processed, verified for coverage and transferred onto CD-ROM. The digital video & Imagery was verified and transferred onto DVD. All data was collected at an approximate altitude of 100 meters with an average ground speed of 17 meters per second.

Wednesday, May 27, 2003: The FLI-MAP® LIDAR system and the crew were demobilized. Data collection for this job was complete. Faron, Terry, and Steve started driving back to Lafayette, La. Connie and Chris drove to Albuquerque, NM to catch plane. Blaine and Morgan flew back to Lafayette, LA.

Thursday, May 29, 2003: Connie and Chris arrive in Lafayette, LA. Faron, Terry, and Steve still driving to Lafayette.

Friday, May 30, 2003: Faron, Terry, and Steve arrive in Lafayette, LA.

FIELD PERSONNEL		
TITLE	**PERSONNEL**	**COMPANY**
Project Supervisor	**Connie Landry**	**John Chance Land Surveys, Inc.**
Project Supervisor	**Faron Olivier**	**John Chance Land Surveys, Inc.**
Data Processor	**Terry Richard**	**John Chance Land Surveys, Inc.**
Department Manager	**Blaine Thibodeaux**	**John Chance Land Surveys, Inc.**
Senior Development Engineer	**Morgan Reed**	**John Chance Land Surveys, Inc.**
FLI-MAP System Operator	**Steve Broussard**	**John Chance Land Surveys, Inc.**
Survey Technician/Data Processor	**Chris Guillory**	**John Chance Land Surveys, Inc.**
Pilot	**Walter Wiser**	**Papillion Helicopters**

4.0 DATA PROCESSING REPORT

4.1 Data Processing Report

Initial Processing: FLI-MAP® processing consists of merging the GPS data collected at the control stations with the GPS, INS, and laser data collected in the helicopter during the flight. The processing of this information produces XYZ coordinates in Flip7®, software written by John E. Chance & Associates, which allows the viewing and data manipulation of FLI-MAP® data. The sequential steps are described as follows:

- GPS and INS data are "unpacked" from the format in which they are collected in the helicopter and are placed in the appropriate data tree structure which separates the data recorded from the two helicopter receivers and the real-time inertial data recorded by the IMU sensor atop the primary laser.
- Once the primary, secondary, GPS, and IMU data are placed in the correct directories, GPS data from the ground control station(s) and the two helicopter receivers are post-processed using OTF kinematic techniques to produce a best fit location of the two helicopter antennas every one half second.
- Position vectors are calculated between the two helicopter antennas and the CRP (common reference point) located in the primary laser using lever arm offsets and real-time IMU data for 3D-angle orientation.
- The aircraft position and attitude data is then merged with the laser information in CHANCE's Flip7® software package to produce XYZ data sets and perform orthometric height modeling.

Utilizing Flip7®, the data is processed to produce the following:

- A complete XYZ data set by computing a XYZ coordinate for 100% of the laser returns. This file represents all physical features detected by the laser.
- Each laser point has a northing, easting, and elevation assigned to it as well as an intensity value and UTC time. Flip7® can then link the laser points with the corresponding time on the video so that the digital image (laser data) and color video of an object in question can be viewed easily.

Field Processing: FLI-MAP® data processing is started in the field to ensure coverage, accuracy, and quality of the data before de-mobilization may occur. All raw data as well as processed data is transferred onto CD-ROM.

DATA PROCESSING

The data from each flight is processed to produce 3D positions of laser returns. The GPS data from the base stations and the primary navigation receiver on the helicopter is reduced kinematically to produce helicopter heading, pitch, and roll results every one half second. Combining this information with John Chance Land Survey's proprietary software, FLIP7, enables the data to be manipulated. A digital terrain model (DTM) can be extracted by classifying those "laser returns" which best define the terrain surface.

Within FLIP7, an appropriate coordinate system is set up and a filtering routine removes vegetation candidates from the data set. The remaining data points are contoured by laser file and remaining outliers are removed. This data is exported in ASCII files and can be read by most third party software formats.

The ASCII data is imported into Terramodel where the data is combined and linked and contoured. The data is then checked again for outliers. Once the DTM has been verified for accuracy the data is written to an appropriate ASCII file or files. These files were written out in a comma delimited file in an "easting, northing, elevation" format.

PROCESSING OF THE SOUTH CANYON SITE

In order to have coverage of the South Canyon site JCLS flew one flight, 030526x1 to collect lidar data. This flight was processed in FLIP7 and filtered to remove vegetation from each lidar file. The data was processed in NAD 83 coordinates State Plain Zone 0202, Arizona Central. The out put coordinates are in meters. The data was next contoured to remove possible outliers. Then it was exported in ASCII format. The river edge was also digitized and exported as a dxf file as well as aerial panel points that were visible in the data set.

This file was imported into Terramodel where it was checked again for outliers and combined with all of the exported files to make one dtm file. The South Canyon area data was then separated into 21 files and exported in about 500,000 points per file sections. A dxf file of the river edge and the 21 areas were also exported at this time.

Data for the South Canyon site is burned onto a CD and includes 21 ASCII xyz files, dxf file, and an aerial panel points file.

PROCESSING OF THE EMINENCE SITE

In order to have coverage of the Eminence site JCLS flew one flight, 030527x1 to collect lidar data. This flight was processed in FLIP7 and filtered to remove vegetation from each lidar file. The data was processed in NAD 83 coordinates State Plain Zone 0202, Arizona Central. The out put coordinates are in meters. The data was next contoured to remove possible outliers. Then it was exported in ASCII format. The river edge was also digitized and exported as a dxf file as well as aerial panel points that were visible in the data set.

This file was imported into Terramodel where it was checked again for outliers and combined with all of the exported files to make one dtm file. The Eminence area data was then separated into 20 files and exported in about 500,000 points per file sections. A dxf file of the river edge and the 20 areas were also exported at this time.

Data for the Eminence site is burned onto a CD and includes 20 ASCII xyz files, dxf file, metafile, and an aerial panel points file.

RAW LASER FILES

JCLS also created ASCII raw xyz data files from FLIP7. These files contain raw processed laser returns so that the information could be imported into third party software. South Canyon (Flight 0526x1) and Eminence (Flight 0527x1) sites were burned each on a CD. The raw data are ASCII space delimited files in an "easting northing elevation" format.

VIDEO

A forward and a down video were encoded and burned to DVD. The imagery is time stamped and can be driven through FLIP7 to correspond with FLIP7 processed laser information. The videos can also be viewed separate of FLIP7. The video data is burned on individual CD disk per flight and perspective (45 and 90) degree camera angles.

DELIVERABLES

JCLS delivered two copies of the following information to

Engineer District, St. Louis, VEMVS_ED_S
(Attn: Robert D. Mesko)
1222 Spruce Street
St. Louis, MO 63103-2833

- Latest Version of FLIP7 (Version 2003.07.04) (1CD)

- FLIP7 project files for flights.

    - Flight 030526x1 (2 CDs)
    - Flight 030527x1 (2 CDs)

- Final dtm files in files of approximately 500,000 points. Dxf file, metafile, and aerial panel points file.

    - Flight 030526x1 (2 CDs)
    - Flight 030527x1 (2 CDs)

- Raw laser files in ASCII format of each flight.

    - Flight 030526x1 (2 CDs)
    - Flight 030527x1 (2 CDs)

- Video MPEGs of each flight's forward, and down imagery.

    - Flight 030526x1 (4 DVDs, 2 at 45 degrees and 2 at 90 degrees)
    - Flight 030527x1 (4 DVDs, 2 at 45 degrees and 2 at 90 degrees)

- Firewire Images of each flight's forward, and down view.

    - Flight 030526x1 (2 DVDs)
    - Flight 030527x1 (2 DVDs)

5.1 GPS COORDINATE ADJUSTMENT SUMMARYS

5.1a FREE ADJUSTMENT

Network Adjustment Report

Project : GCMRC_2003

User name	cel	**Date & Time**	4:04:11 PM 06/09/2003
Coordinate System	US State Plane 1983	**Zone**	Arizona Central 0202
Project Datum	NAD 1983 (Conus)		
Vertical Datum	Ellipsoidal heights	**Geoid Model**	GEOID99 (Conus)
Coordinate Units	Meters		
Distance Units	Meters		
Height Units	Meters		

Adjustment Style Settings - 95% Confidence Limits

Residual Tolerances

To End Iterations : 0.000010m

Final Convergence Cutoff : 0.005000m

Covariance Display

Horizontal

Propogated Linear Error [E] : U.S.

Constant Term [C] : 0.00000000m

Scale on Linear Error [S] : 1.96

Three-Dimensional

Propogated Linear Error [E] : U.S.

Constant Term [C] : 0.00000000m

Scale on Linear Error [S] : 1.96

Elevation Errors were used in the calculations.

Adjustment Controls

Compute Correlations for Geoid : False

Horizontal and Vertical adjustment performed

Set-up Errors

GPS
Error in Height of Antenna : 0.001m
Centering Error : 0.001m

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Statistical Summary

Successful Adjustment in 1 iteration(s)

Network Reference Factor : 1.03
Chi Square Test (α=95%) : PASS
Degrees of Freedom : 12.00

GPS Observation Statistics

Reference Factor : 1.03
Redundancy Number (r) : 12.00

Individual GPS Observation Statistics

Observation ID	Reference Factor	Redundancy Number
B2	0.88	2.19
B5	1.29	0.58
B8	0.89	0.91
B9	1.04	1.33
B12	1.24	2.19
B14	0.63	0.66
B16	1.27	2.06
B20	0.66	2.09

B24	1.00	0.00

Weighting Strategies

GPS Observations

User-defined Scalar Applied to All Observations

Scalar : 7.04

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Adjusted Coordinates

Adjustment performed in WGS-84

Number of Points : 6
Number of Constrained Points : 1
Horizontal and Height Only : 1

Adjusted Grid Coordinates

Errors are reported using 1.96σ.

Point Name	Northing	N error	Easting	E error	Elevation	e error	Fix
EMIN	599267.973m	0.000m	221056.274m	0.000m	N/A	N/A	N E h
SCTH	607113.236m	0.006m	212416.689m	0.005m	N/A	N/A	
DSVW	559039.781m	0.008m	221146.265m	0.006m	N/A	N/A	
L404	650702.434m	0.007m	250206.447m	0.005m	N/A	N/A	
BCTH	610746.876m	0.006m	214688.936m	0.004m	N/A	N/A	
FRED	664333.415m	0.018m	161504.365m	0.014m	N/A	N/A	

Adjusted Geodetic Coordinates

Errors are reported using 1.96σ.

Point Name	Latitude	N error	Longitude	E error	Height	h error	Fix
EMIN	36°24'12.03777"N	0.000m	111°49'51.09660"W	0.000m	1742.567m	0.000m	Lat Long

							h
SCTH	36°28'26.68879"N	0.006m	111°55'37.89583"W	0.005m	1676.303m	0.014m	
DSVW	36°02'26.77444"N	0.008m	111°49'48.92358"W	0.006m	2263.404m	0.017m	
L404	36°51'58.31245"N	0.007m	111°30'12.23482"W	0.005m	1314.374m	0.014m	
BCTH	36°30'24.58059"N	0.006m	111°54'06.58991"W	0.004m	1611.524m	0.012m	
FRED	36°59'17.97790"N	0.018m	112°29'57.13542"W	0.014m	1530.766m	0.035m	

Coordinate Deltas

Point Name	ΔNorthing	ΔEasting	ΔElevation	ΔHeight	ΔGeoid Separation
EMIN	0.000m	0.000m	N/A	0.000m	N/A
SCTH	0.000m	0.000m	N/A	0.000m	N/A
DSVW	0.000m	0.000m	N/A	0.000m	N/A
L404	0.000m	0.000m	N/A	0.000m	N/A
BCTH	0.000m	0.000m	N/A	0.000m	N/A
FRED	0.000m	0.000m	N/A	0.000m	N/A

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Control Coordinate Comparisons

Values shown are control coord minus adjusted coord.

Point Name	ΔNorthing	ΔEasting	ΔElevation	ΔHeight
EMIN	N/A	N/A	N/A	N/A
DSVW	-0.004m	0.007m	N/A	-0.006m
L404	-0.003m	0.007m	N/A	0.067m
FRED	-0.002m	0.003m	N/A	-0.021m

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Adjusted Observations

Adjustment performed in WGS-84

GPS Observations

Number of Observations : 9

Number of Outliers : 0

Observation Adjustment (Critical Tau = 2.64). Any outliers are in red.

Obs. ID	From Pt.	To Pt.		Observation	A-posteriori Error (1.96σ)	Residual	Stand. Residual
B16	L404	DSVW	**Az.**	197°50'11.6733"	0°00'00.0170"	0°00'00.0102"	0.80
			ΔHt.	949.030m	0.020m	-0.027m	-1.92
			Dist.	96167.854m	0.009m	0.005m	0.64
B5	EMIN	DSVW	**Az.**	179°55'21.1170"	0°00'00.0323"	-0°00'00.0067"	-0.89
			ΔHt.	520.837m	0.017m	0.009m	1.86
			Dist.	40232.285m	0.008m	0.000m	0.09
B9	EMIN	BCTH	**Az.**	331°02'01.9524"	0°00'00.0747"	0°00'00.0038"	0.11
			ΔHt.	-131.043m	0.012m	-0.009m	-1.69
			Dist.	13127.931m	0.005m	-0.001m	-0.41
B12	EMIN	SCTH	**Az.**	312°17'32.2366"	0°00'00.0936"	-0°00'00.0420"	-0.45
			ΔHt.	-66.264m	0.014m	0.016m	1.67
			Dist.	11671.236m	0.005m	-0.007m	-1.49
B2	EMIN	SCTH	**Az.**	312°17'32.2366"	0°00'00.0936"	0°00'00.0364"	0.61
			ΔHt.	-66.264m	0.014m	-0.018m	-0.57
			Dist.	11671.236m	0.005m	0.005m	1.49
B14	SCTH	BCTH	**Az.**	32°00'46.7252"	0°00'00.2120"	0°00'00.0013"	0.02
			ΔHt.	-64.779m	0.010m	0.003m	1.29
			Dist.	4286.038m	0.005m	0.000m	0.19
B8	EMIN	L404	**Az.**	29°35'37.2965"	0°00'00.0202"	-0°00'00.0075"	-1.07
			ΔHt.	-428.193m	0.014m	-0.005m	-0.88
			Dist.	59126.024m	0.006m	-0.001m	-0.45
B20	BCTH	L404	**Az.**	41°38'38.0660"	0°00'00.0275"	0°00'00.0145"	0.70
			ΔHt.	-297.150m	0.017m	-0.008m	-0.69

			Dist.	53464.743m	0.007m	0.002m	0.30
B24	EMIN	FRED	**Az.**	317°35'01.2719"	0°00'00.0385"	0°00'00.0000"	0.00
			ΔHt.	-211.801m	0.035m	0.000m	0.00
			Dist.	88211.948m	0.016m	0.000m	0.00

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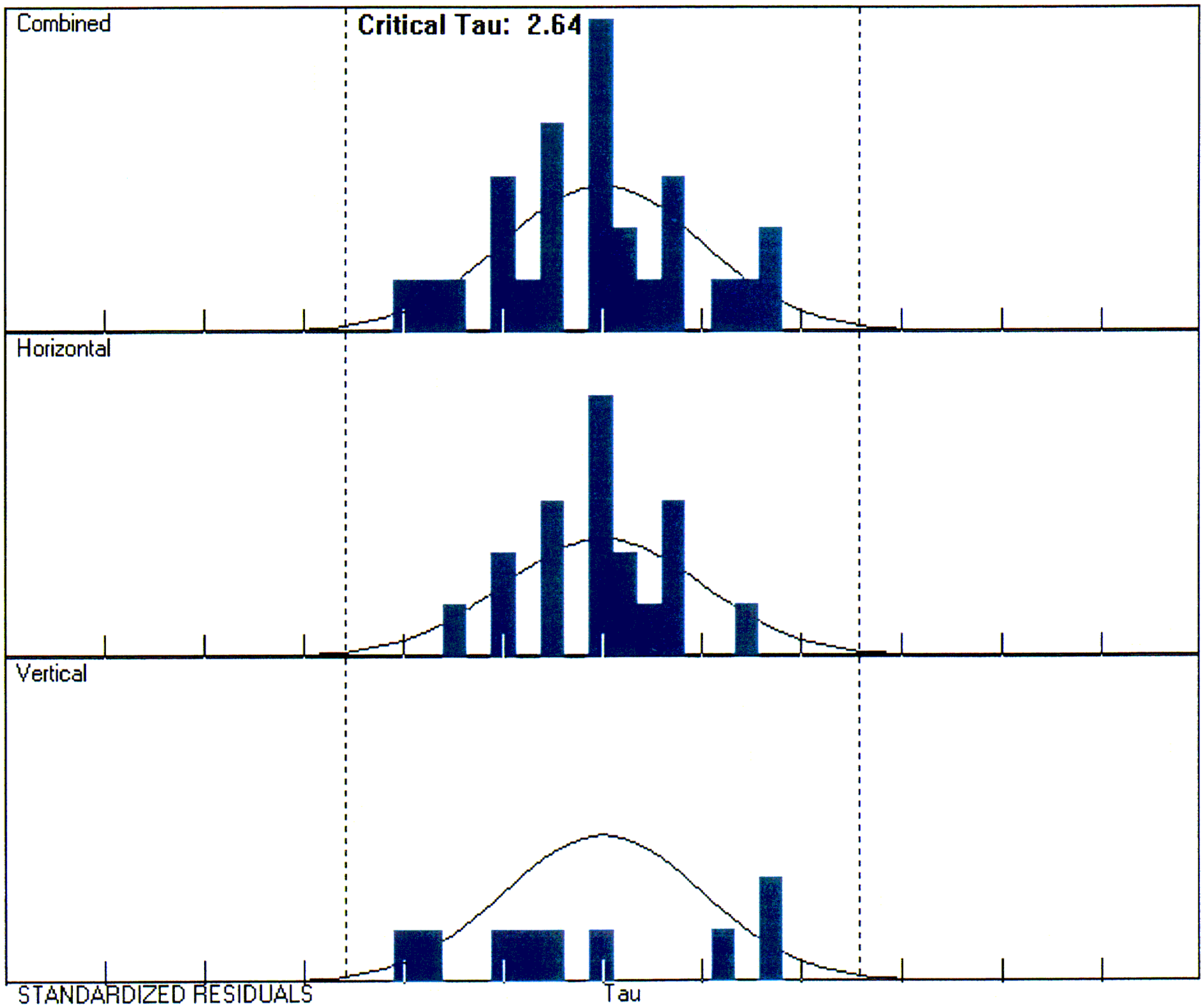
Histograms of Standardized Residuals



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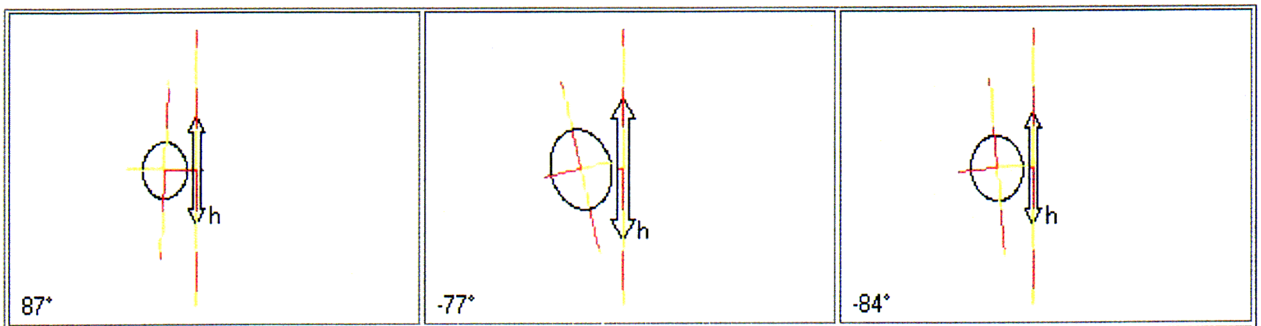
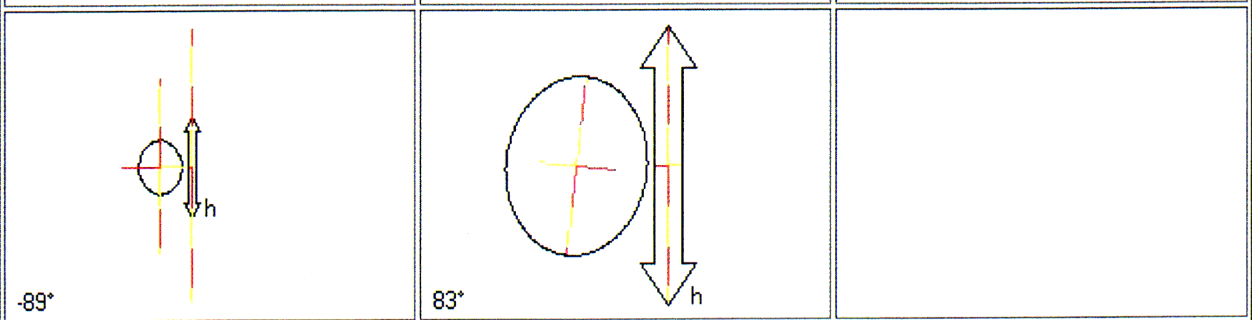
Point Error Ellipses

SCTH	DSVW	L404



Tick Size: 0.0100m   Horizontal Bivariate Scalar: 2.45σ   Vertical Univariate Scalar: 1.96σ

BCTH	FRED	



Tick Size: 0.0100m   Horizontal Bivariate Scalar: 2.45σ   Vertical Univariate Scalar: 1.96σ

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Covariant Terms

Adjustment performed in WGS-84

From Point	To Point		Components	A-posteriori Error (1.96σ)	Horiz. Precision (Ratio)	3D Precision (Ratio)
EMIN	SCTH	**Az.**	312°17'32.2366"	0°00'00.0936"	1:2293589	1:2293589
		ΔHt.	-66.264m	0.014m		
		ΔElev.	?	?		
		Dist.	11671.236m	0.005m		
EMIN	DSVW	**Az.**	179°55'21.1170"	0°00'00.0323"	1:4994691	1:4994691
		ΔHt.	520.837m	0.017m		
		ΔElev.	?	?		
		Dist.	40232.285m	0.008m		
EMIN	L404	**Az.**	29°35'37.2965"	0°00'00.0202"	1:9563459	1:9563459

		ΔHt.	-428.193m	0.014m		
		ΔElev.	?	?		
		Dist.	59126.024m	0.006m		
EMIN	BCTH	**Az.**	331°02'01.9524"	0°00'00.0747"	1:2449366	1:2449366
		ΔHt.	-131.043m	0.012m		
		ΔElev.	?	?		
		Dist.	13127.931m	0.005m		
EMIN	FRED	**Az.**	317°35'01.2719"	0°00'00.0385"	1:5562283	1:5562283
		ΔHt.	-211.801m	0.035m		
		ΔElev.	?	?		
		Dist.	88211.948m	0.016m		
SCTH	BCTH	**Az.**	32°00'46.7252"	0°00'00.2120"	1:882848	1:882848
		ΔHt.	-64.779m	0.010m		
		ΔElev.	?	?		
		Dist.	4286.038m	0.005m		
DSVW	L404	**Az.**	17°38'32.5008"	0°00'00.0168"	1:10534124	1:10534124
		ΔHt.	-949.030m	0.020m		
		ΔElev.	?	?		
		Dist.	96167.854m	0.009m		
L404	BCTH	**Az.**	221°52'55.0083"	0°00'00.0276"	1:7423999	1:7423999
		ΔHt.	297.150m	0.017m		
		ΔElev.	?	?		
		Dist.	53464.743m	0.007m		

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St. Louis District COE / Grand Canyon Monitoring & Research Center

South Canyon & Eminence Sites

Grand Canyon, Arizona

JCLS Job # 03-6027

Constrained Adjustment

NAME		POSITION (NAD83)	ELLIP METERS	PUB. ELLIP METERS	PUB. DELTA GPS METERS	DESCRIPTION
SCTH	N	36 28 26.68880	1676.303			Temporary Station
	W	111 55 37.89581				Set by GCMRC (Future Bluebook)
DSVW	N	36 02 26.77433	2263.407	2263.398	0.009	DESERT VIEW
	W	111 49 48.92330				PID AJ5640
EMIN	N	36 24 12.03777	1742.567	1742.567	0.000	EMIN
	W	111 49 51.09660				PID AJ5639
L404	N	36 51 58.31235	1314.377	1314.441	-0.064	L 404
	W	111 30 12.23455				PID GP0283
BCTH	N	36 30 24.58059	1611.524			Temporary Station
	W	111 54 06.58988				
FRED	N	36 59 17.97802	1530.766	1530.750	0.016	FREDONIA CORS L1 PHASE CENTER
	W	112 29 57.13539				PID AI8806

Note: The positions of the control stations listed above are referenced to NAD83(2001 FBN Arizona) horizontally & (2001 FBN Arizona) ellipsodal heights vertically. These coordinates were used as control for the FLI-MAP survey performed on May 2003. Reference section 5.1C (communications) for the email containing the 2001 FBN Arizona coordinates provided by Keith Kohl (GCMRC Survey Department).

The horizontal positions were computed in a least squares adjustment of the GPS data by holding to the published position of "DSVW", "EMIN", & "L404".

The vertical positions (ellipsoidal heights) were computed in a least squares adjustment of the GPS data by holding to a published ellipsoidal height of "EMIN".

5.1b CONSTRAINED ADJUSTMENT

Network Adjustment Report

Project : GCMRC_2003

User name	cel	**Date & Time**	4:08:05 PM 06/09/2003
Coordinate System	US State Plane 1983	**Zone**	Arizona Central 0202
Project Datum	NAD 1983 (Conus)		
Vertical Datum	Ellipsoidal heights	**Geoid Model**	GEOID99 (Conus)
Coordinate Units	Meters		
Distance Units	Meters		
Height Units	Meters		

Adjustment Style Settings - 95% Confidence Limits

Residual Tolerances

To End Iterations : 0.000010m
Final Convergence Cutoff : 0.005000m

Covariance Display

Horizontal
Propogated Linear Error [E] : U.S.
Constant Term [C] : 0.00000000m
Scale on Linear Error [S] : 1.96

Three-Dimensional
Propogated Linear Error [E] : U.S.
Constant Term [C] : 0.00000000m
Scale on Linear Error [S] : 1.96

Elevation Errors were used in the calculations.

Adjustment Controls

Compute Correlations for Geoid : False

Horizontal and Vertical adjustment performed

Set-up Errors

GPS

Error in Height of Antenna : 0.001m

Centering Error : 0.001m

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Statistical Summary

Successful Adjustment in 1 iteration(s)

Network Reference Factor : 1.26

Chi Square Test (α=95%) : PASS

Degrees of Freedom : 14.00

GPS Observation Statistics

Reference Factor : 1.26

Redundancy Number (r) : 14.00

Individual GPS Observation Statistics

Observation ID	Reference Factor	Redundancy Number
B2	0.81	2.19
B5	2.18	1.87
B8	0.95	1.40
B9	1.10	1.34
B12	1.29	2.19
B14	0.66	0.67
B16	1.12	2.15
B20	1.06	2.19

B24	1.00	0.00

Weighting Strategies

GPS Observations
User-defined Scalar Applied to All Observations

Scalar : 7.04

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Adjusted Coordinates

Adjustment performed in WGS-84

Number of Points	: 6
Number of Constrained Points	: 3
Horizontal Only	: 2
Horizontal and Height Only	: 1

Adjusted Grid Coordinates

Errors are reported using 1.96σ.

Point Name	Northing	N error	Easting	E error	Elevation	e error	Fix
EMIN	599267.973m	0.000m	221056.274m	0.000m	N/A	N/A	N E h
SCTH	607113.236m	0.007m	212416.689m	0.006m	N/A	N/A	
DSVW	559039.778m	0.000m	221146.272m	0.000m	N/A	N/A	N E
L404	650702.431m	0.000m	250206.453m	0.000m	N/A	N/A	N E
BCTH	610746.876m	0.007m	214688.937m	0.006m	N/A	N/A	
FRED	664333.418m	0.023m	161504.365m	0.020m	N/A	N/A	

Adjusted Geodetic Coordinates

Errors are reported using 1.96σ.

Point Name	Latitude	N error	Longitude	E error	Height	h error	Fix
EMIN	36°24'12.03777"N	0.000m	111°49'51.09660"W	0.000m	1742.567m	0.000m	Lat

							Long h
SCTH	36°28'26.68879"N	0.007m	111°55'37.89581"W	0.006m	1676.303m	0.017m	
DSVW	36°02'26.77433"N	0.000m	111°49'48.92330"W	0.000m	2263.407m	0.021m	Lat Long
L404	36°51'58.31235"N	0.000m	111°30'12.23455"W	0.000m	1314.377m	0.017m	Lat Long
BCTH	36°30'24.58059"N	0.007m	111°54'06.58988"W	0.006m	1611.524m	0.015m	
FRED	36°59'17.97802"N	0.023m	112°29'57.13539"W	0.020m	1530.766m	0.043m	

Coordinate Deltas

Point Name	ΔNorthing	ΔEasting	ΔElevation	ΔHeight	ΔGeoid Separation
EMIN	0.000m	0.000m	N/A	0.000m	N/A
SCTH	0.000m	0.000m	N/A	0.000m	N/A
DSVW	0.000m	0.000m	N/A	0.003m	N/A
L404	0.000m	0.000m	N/A	0.003m	N/A
BCTH	0.000m	0.001m	N/A	0.000m	N/A
FRED	0.004m	0.001m	N/A	0.000m	N/A

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Control Coordinate Comparisons

Values shown are control coord minus adjusted coord.

Point Name	ΔNorthing	ΔEasting	ΔElevation	ΔHeight
EMIN	N/A	N/A	N/A	N/A
DSVW	N/A	N/A	N/A	-0.009m
L404	N/A	N/A	N/A	0.064m
FRED	-0.006m	0.002m	N/A	-0.021m

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Adjusted Observations

Adjustment performed in WGS-84

GPS Observations

GPS Transformation Group: <GPS Default>

Azimuth Rotation : -0°00'00.0070" **(1.96σ)** : 0°00'00.0193"

Network Scale : 0.99999998 **(1.96σ)** : 0.00000011

Number of Observations : 9

Number of Outliers : 0

Observation Adjustment (Critical Tau = 2.71). Any outliers are in red.

Obs. ID	From Pt.	To Pt.		Observation	A-posteriori Error (1.96σ)	Residual	Stand. Residual
B5	EMIN	DSVW	**Az.**	179°55'21.0737"	0°00'00.0193"	-0°00'00.0500"	-2.50
			ΔHt.	520.840m	0.021m	0.012m	1.86
			Dist.	40232.288m	0.004m	0.003m	0.53
B16	L404	DSVW	**Az.**	197°50'11.6658"	0°00'00.0193"	0°00'00.0027"	0.16
			ΔHt.	949.030m	0.024m	-0.027m	-1.55
			Dist.	96167.852m	0.010m	0.002m	0.27
B12	EMIN	SCTH	**Az.**	312°17'32.2355"	0°00'00.1150"	-0°00'00.0430"	-0.37
			ΔHt.	-66.264m	0.017m	0.016m	1.38
			Dist.	11671.236m	0.006m	-0.007m	-1.31
B9	EMIN	BCTH	**Az.**	331°02'01.9559"	0°00'00.0916"	0°00'00.0073"	0.18
			ΔHt.	-131.043m	0.015m	-0.008m	-1.31
			Dist.	13127.930m	0.007m	-0.002m	-0.57
B20	BCTH	L404	**Az.**	41°38'38.0846"	0°00'00.0300"	0°00'00.0331"	1.24
			ΔHt.	-297.148m	0.021m	-0.006m	-0.40
			Dist.	53464.744m	0.008m	0.002m	0.27
B2	EMIN	SCTH	**Az.**	312°17'32.2355"	0°00'00.1150"	0°00'00.0354"	0.48
			ΔHt.	-66.264m	0.017m	-0.018m	-0.46
			Dist.	11671.236m	0.006m	0.005m	1.10

B14	SCTH	BCTH	**Az.**	32°00'46.7410"	0°00'00.2603"	0°00'00.0170"	0.21
			ΔHt.	-64.779m	0.012m	0.003m	1.09
			Dist.	4286.038m	0.006m	0.000m	0.13
B8	EMIN	L404	**Az.**	29°35'37.3160"	0°00'00.0193"	0°00'00.0120"	1.02
			ΔHt.	-428.190m	0.017m	-0.002m	-0.27
			Dist.	59126.023m	0.006m	-0.002m	-0.58
B24	EMIN	FRED	**Az.**	317°35'01.2719"	0°00'00.0473"	0°00'00.0000"	0.00
			ΔHt.	-211.801m	0.043m	0.000m	0.00
			Dist.	88211.948m	0.019m	0.000m	0.00

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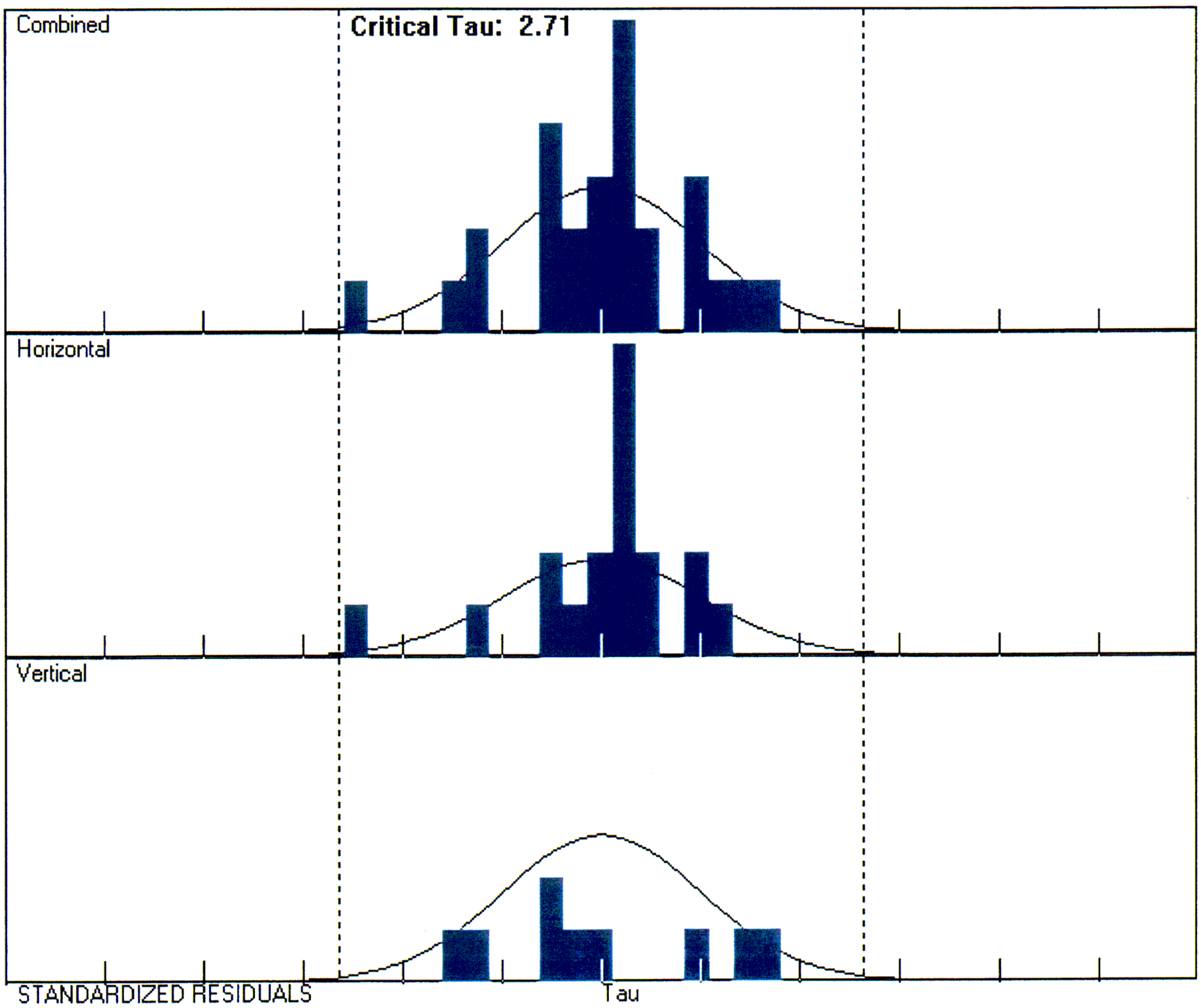
Histograms of Standardized Residuals



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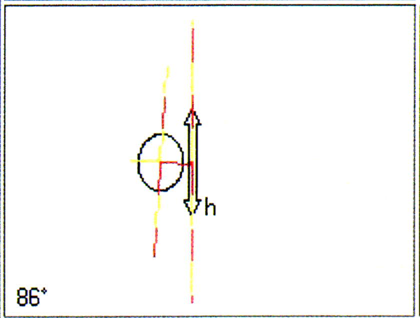
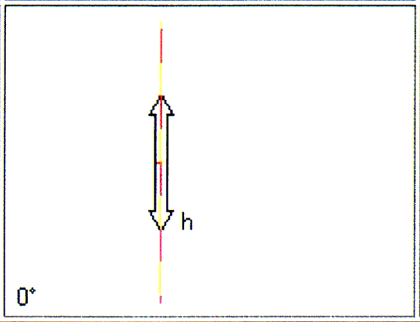
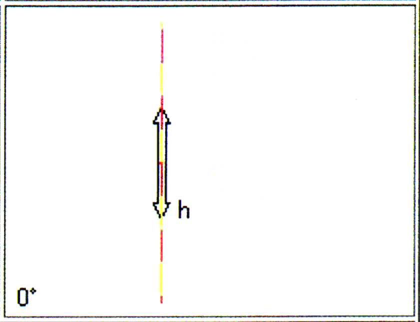
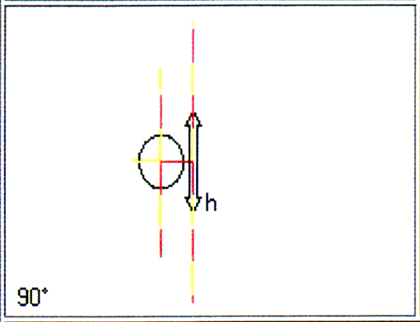
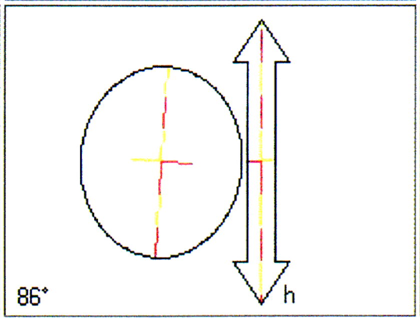
Point Error Ellipses

SCTH	DSVW	L404
		
Tick Size: 0.0100m Horizontal Bivariate Scalar: 2.45σ Vertical Univariate Scalar: 1.96σ		
BCTH	**FRED**	
		
Tick Size: 0.0100m Horizontal Bivariate Scalar: 2.45σ Vertical Univariate Scalar: 1.96σ		

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Covariant Terms

Adjustment performed in WGS-84

From Point	To Point		Components	A-posteriori Error (1.96σ)	Horiz. Precision (Ratio)	3D Precision (Ratio)
EMIN	SCTH	**Az.**	312°17'32.2425"	0°00'00.1168"	1:1849000	1:1849000
		ΔHt.	-66.264m	0.017m		
		ΔElev.	?	?		
		Dist.	11671.236m	0.006m		
EMIN	DSVW	**Az.**	179°55'21.0807"	0°00'00.0000"	1:0	1:0

		ΔHt.	520.840m	0.021m		
		ΔElev.	?	?		
		Dist.	40232.289m	0.000m		
EMIN	L404	**Az.**	29°35'37.3229"	0°00'00.0000"	1:0	1:0
		ΔHt.	-428.190m	0.017m		
		ΔElev.	?	?		
		Dist.	59126.025m	0.000m		
EMIN	BCTH	**Az.**	331°02'01.9629"	0°00'00.0928"	1:2000653	1:2000653
		ΔHt.	-131.043m	0.015m		
		ΔElev.	?	?		
		Dist.	13127.931m	0.007m		
EMIN	FRED	**Az.**	317°35'01.2789"	0°00'00.0511"	1:4078604	1:4078604
		ΔHt.	-211.801m	0.043m		
		ΔElev.	?	?		
		Dist.	88211.950m	0.022m		
SCTH	BCTH	**Az.**	32°00'46.7480"	0°00'00.2599"	1:719509	1:719509
		ΔHt.	-64.779m	0.012m		
		ΔElev.	?	?		
		Dist.	4286.039m	0.006m		
DSVW	L404	**Az.**	17°38'32.5002"	0°00'00.0000"	1:0	1:0
		ΔHt.	-949.030m	0.024m		
		ΔElev.	?	?		
		Dist.	96167.854m	0.000m		
L404	BCTH	**Az.**	221°52'55.0341"	0°00'00.0238"	1:8450523	1:8450523
		ΔHt.	297.148m	0.021m		
		ΔElev.	?	?		
		Dist.	53464.745m	0.006m		

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5.1c COMMUNICATIONS

From: Keith Kohl [kkohl@usgs.gov]
Sent: Monday, June 09, 2003 10:30 AM
To: Landry, Connie
Subject: Re: FW: Survey Control

Connie,

The ellipsoidal height that I used for GPS surveys around EMIN is the 2001 FBN survey result of 1742.567 meters in NAD 83(1992). NGS datasheets are not updated unless coordinates change by 5 cm until the 2005 NSRS adjustment

I will not have revised coordinates for the points until the results are run through Pages and Adjust, and the blue booking is completed with the assisstance of the NGS state advisor.

Keith

"Landry, Connie"

<CLandry@jchance.com>

"Thibodeaux, Blaine"

06/06/2003 11:58AM

To: "'Keith Kohl'" <kkohl@usgs.gov>
cc: "'fmgonz@usgs.gov'" <fmgonz@usgs.gov>, <BThibodeaux@jchance.com>
Subject: FW: Survey Control

Mark & Keith.

Have you had an opportunity to review the e-mail below? Will you be able to offer any guidance?

-----Original Message-----
From: Landry, Connie
Sent: Wednesday, June 04, 2003 10:39 AM
To: 'Keith Kohl'; 'F. Mark Gonzales'
Cc: Thibodeaux, Blaine
Subject: FW: Survey Control

Keith & Mark,

I have given some additional thought to our quandary. I have a question - but 1st let me explain our process.

Static surveys are performed prior to or during FLI-MAP data collection for 3 reasons: 1) to proliferate control stations closer to the project area 2) to verify that the existing control coordinate values will be sufficient or "up to date" and 3) to check observed GPS data against published information (when available).

JCLS will perform the network adjustment and end up with a horizontally constrained adjustment (2 or more constraints) and a vertically free adjustment. In the case of this project 3 horizontal constraints (L404, EMIN & DSVW) and 1 vertical constraint (EMIN). EMIN was chosen as the vertical constraint due to the fact that it is closest to the area of interest. Stations L404 & DSVW are utilized as vertical quality control and their respective heights will not be utilized to compute the positions of the 2 newly set stations (SCTH & BCTH) used as control for the FLI-MAP data collection.

Keith - from the information you have already provided we have 2 potential heights for EMIN:
1742.567 2001- FBN Arizona
1742.55 NGS published

I assume one of these heights will be used as the vertical constraint in our adjustment. The difference between these two heights is 0.017m.

Now the question. Which of these two heights is closer to the height (or is the height) utilized for EMIN when controlling survey data collected within the canyon at Eminence and South Canyon? That will be the height we would prefer to utilize.

On another note - all of the data collected during the FLI-MAP mission is archived. If at some point in the future "up to date" coordinates are produced, the FLI-MAP data can be reprocessed - if the magnitude of coordinate change is significant.

Thanks for your patience on this issue.

-----Original Message-----
From: Landry, Connie
Sent: Wednesday, June 04, 2003 10:50 AM
To: 'Keith Kohl'
Subject: RE: Survey Control

Keith,

Sorry about the lack of detail. I loaded the baseline between EMIN and FRED into the static adjustment I already had for the project.

I held to the published ellip. height of EMIN (1742.55).

-----Original Message-----
From: Keith Kohl [mailto:kkohl@usgs.gov]
Sent: Tuesday, June 03, 2003 5:40 PM
To: Landry, Connie
Subject: RE: Survey Control

Connie,

What was the height value you used at EMIN?

Keith

"Landry, Connie"<CLandry@jchance.
To: "'Keith Kohl'"<kkohl@usgs.gov>com>
cc: "F. Mark Gonzales"<fmgonz@usgs.gov>
Subject: RE: Survey Control
06/03/2003 02:57PM

Keith,

I processed the baseline between Fredonia CORS and EMIN. I held to EMIN in the free adjustment and computed an ellipsoidal height of 1530.749 on the phase center of the antenna at Fredonia. The published ellipsoidal height for the Fredonia CORS phase center is 1530.745.

-----Original Message-----
From: Landry, Connie
Sent: Monday, June 02, 2003 5:03 PM
To: 'Keith Kohl'
Cc: F. Mark Gonzales; Thibodeaux, Blaine
Subject: RE: Survey Control

Keith,

Thanks for the feedback. The height deltas from September 2001 and February

2002 are very interesting - as they were generated from a free adjustment. Prior to receiving these values - I was concerned that the fbn 2001 delta of 428.126 may have been a result of multiple constraints within that network. Having said that - the same could also be true for the published coordinate deltas.

It never ceases to amaze me that we have grown to the point that we are concerned about a few centimeters.

I do not think that adding the CORS stations at Fredonia and/or Fern Mesa will change the delta height between L404 and EMIN. But I will investigate and forward the results.

-----Original Message-----
From: Keith Kohl [mailto:kkohl@usgs.gov]
Sent: Monday, June 02, 2003 4:48 PM
To: Landry, Connie
Cc: F. Mark Gonzales
Subject: RE: Survey Control

Connie,

Here are some more interesting values. Two surveys were performed in September 2001 and February 2002 that occupied both EMIN and L404. The resulting free adjustment gave the following results.

428.143	delta height EMIN & L404 February, 2002 (18 hours static data)
428.135	delta height EMIN & L404 September, 2001 (18 hours static data)

Since these values were closer to the fbn2001 result of 428.126 rather than the published 428.18 from NGS, I stayed with the unpublished fbn2001 values available from the AZ state land department that were adjusted holding COSA in Scottsdale fixed.

I'm sure you want to move along on the kinematic processing, however, until I can process the recent data with the 4 local CORS stations that were not available during the 1999 and 2001 fbn surveys, I regret that I can't give you centimeter heights. Have you brought into your adjustment CORS stations at Fredonia and Fern Mesa?

Let me know what you decide to do.

Thank you,

Keith

Keith Kohl
GCMRC Survey Department
(928) 556-7371

"Landry, Connie"<CLandry@jchance.
To: "'Keith Kohl'"<kkohl@usgs.gov>, "F. Mark Gonzales"com><fmgonz@usgs.gov>
cc: "Thibodeaux,Blaine" <BThibodeaux@jchance.com>
06/02/2003 12:07PM
Subject: RE: Survey Control

Keith & Mark,

Here are some interesting values:

428.126 delta height between EMIN & L404 - 2001-fbn Arizona (values listed below).
428.191 delta height between EMIN & L404 - 2003 JCLS survey (free adjustment).
428.18 delta height between EMIN & L404 - published NGS values.

Which control values for EMIN have been utilized in the past by the GCMRC to constrain control surveys? Which control values will be utilized to QC the 2003 FLI-MAP project? We want to hold to the coordinates that will match the coordinates utilized by the GCMRC.

We will await your guidance!!

-----Original Message-----
From: Keith Kohl [mailto:kkohl@usgs.gov]
Sent: Monday, June 02, 2003 12:57 PM
To: F. Mark Gonzales; clandry@jchance.com
Subject: Re: Survey Control

Connie,

In response to your heights for EMIN, Desert View, and L404

L404 was occupied for two seperate FBN surveys. The 1999 fbn with Nevada and Utah gave L404 an ellipsoid height of 1314.375. The 2001 fbn with Arizona resulted in an ellipsoid height of 1314.441 or 6.6 cm higher. NGS still publishes the height at 1314.37 but it appears that the 2001-fbn value may be closer to the true ellipsoid height. The recent static survey was meant to clarify coordinates adjusted between adjoining states.

Values of the 2001- FBN Arizona (February 2001 data collection; July 2001 results by PAGES (NGS GPS processing software) and ADJUST (NGS network adjustment software)

Desert View	36 02 26.77433	111 49 48.92330	2263.398
EMIN	36 24 12.03777	111 49 51.09660	1742.567
L404	36 51 58.31235	111 30 12.23455	1314.441

Keith Kohl: GCMRC Survey Department
(928) 556-7371

F. Mark Gonzales

To: Keith
Kohl/BRD/USGS/DOI@USGS
05/30/2003 03:32
cc:

PM Subject: Survey Control

----- Forwarded by F. Mark Gonzales/BRD/USGS/DOI on 05/30/2003 03:32 PM

"Landry, Connie"
<CLandry@jchance. To: clandry@
jchance.com,"'fmgonz@usgs.gov'" <fmgonz@usgs.gov>com>
cc:
Subject: Survey Control
05/30/2003 01:31PM

Mark,

We utilized the following control station as our constraints for the static survey. EMIN, Desert View & L 404.

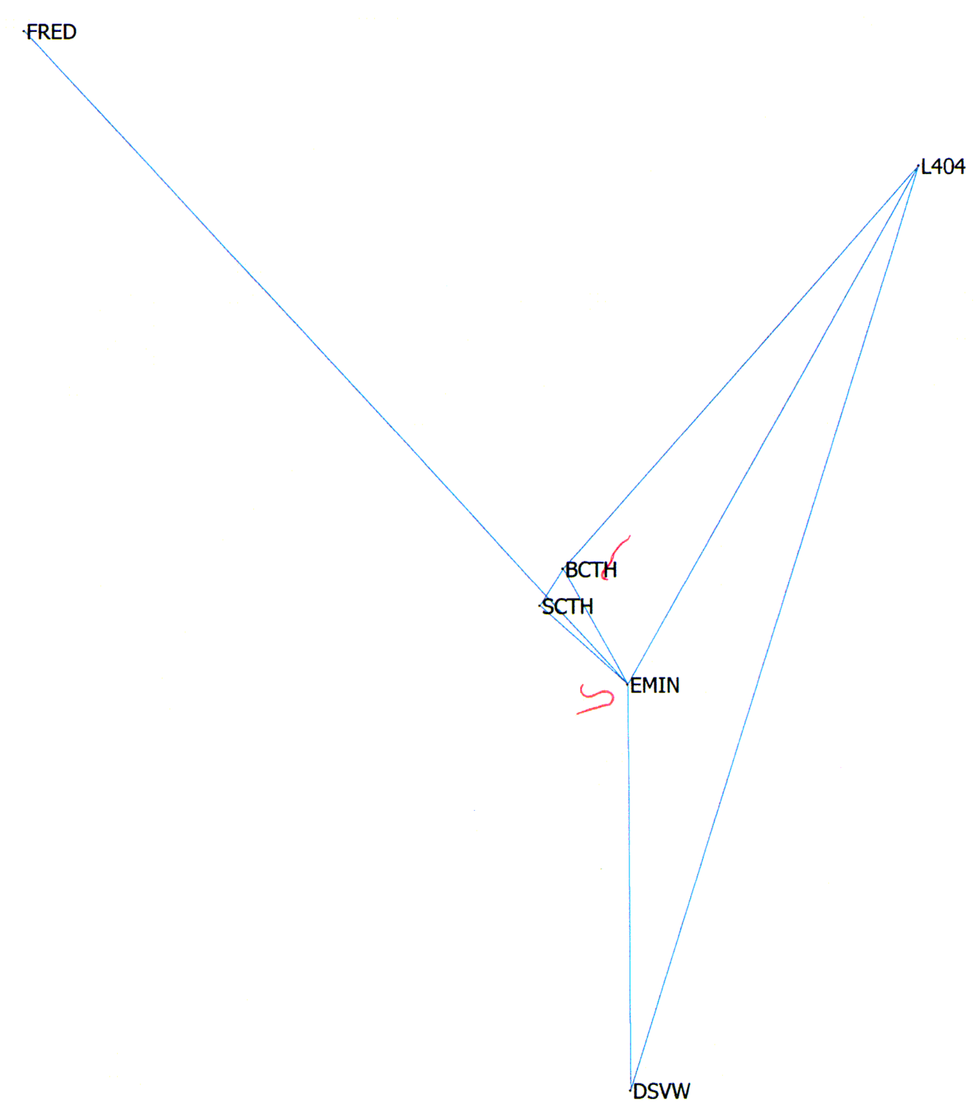
<<emin.txt>> <<desert view.txt>> <<L404.txt>>
The ellipsoidal heights are published to 2 decimal places. Do you have access to ellipsoidal heights published to 3 decimal places? If so would you forward those to me?

Thank you in advance. Hope your static survey was successful.

Connie Landry - Supervisor Field Operations
John Chance Land Surveys, Inc.
FLI-MAP Division
Phone: 337-268-3294
Fax : 337-268-3392
Cell: 337-962-0161
Beeper: 1-800-946-4646 Pin #1440882
E-Mail: clandry@ jchance.com

(See attached file: emin.txt)(See attached file: desert view.txt)(See attached file: L404.txt)

5.2 SURVEY CONTROL MAPS



Field surveyc
Connie Landry
Computer operator:

Reference:
JCLS Job Number 03-6027

Scale 1:750000
0 35000 m
Meters

0°00'00"

Plot Scale: 1:750000
Printed on 06/10/2003, at 3:26:21 PM

Printed from Trimble Geomatics Office

Site: Not selected, System: US State Plane 1983
Zone: Arizona Central 0202, Datum: NAD 1983 (Conus)

Project: GCMRC_2003
Metric Template

5.3 SYSTEM ACCURACY CHECK INFORMATION

BASE STATION CHECK

St. Louis District COE / Grand Canyon Monitoring & Research Center
South Canyon & Eminence Sites
Grand Canyon, Arizona
JCLS JOB #03-6027

FLIGHT	NAME		New Mexico Central METERS	PUB. ELLIP ELEV. METERS	TRUE VERT. ANT. HGT METERS	ANT. ORTHO. HGT. METERS		FLIP7 New Mexico Central METERS	FLIP7 ELLIP ELEV. METERS	DELTA NORTHING METERS	DELTA EASTING METERS	DELTA NAVD 88 ELEV. METERS
030526X1	BCTH	N	610746.870	1611.510	1.552	1613.062	N	610746.86	1613.07	0.01		-0.008
		E	214688.950				E	214688.98			-0.03	
030526X2	EMIN	N	599267.970	1742.550	1.398	1743.948	N	599267.93	1744	0.04		-0.052
		E	221056.290				E	221056.21			0.08	

BASE STATION CHECK

St. Louis District COE / Grand Canyon Monitoring & Research Center
South Canyon & Eminence Sites
Grand Canyon, Arizona
JCLS JOB #03-6027

FLIGHT	NAME		New Mexico Central METERS	PUB. ELLIP ELEV. METERS	TRUE VERT. ANT. HGT METERS	ANT. ORTHO. HGT. METERS		FLIP7 New Mexico Central METERS	FLIP7 ELLIP ELEV. METERS	DELTA NORTHING METERS	DELTA EASTING METERS	DELTA NAVD 88 ELEV. METERS
030527X1	EMIN	N	599267.970	1742.550	1.443	1743.993	N	599267.96	1744.02	0.01		-0.027
		E	221056.290				E	221056.27			0.02	

5.4 ANTENNA HEIGHT INFORMATION SHEETS

JOHN CHANCE LAND SURVEYS, INC.
FLI-MAP GPS DATA SHEET
CORRIDOR MAPPING

CLIENT / PROJECT AREA: Grand Canyon Monitoring and Research

Observer: Chris Wk/Day: Sunday Date: ______ Job ______

	SESSION 1	SESSION 2	SESSION 3	SESSION 4
Station ID:	BCTH	BCTH		
Julian Date:				
Local Start Time:	10:00	12:05		
Survey Time:				
Local Stop Time:	12:00	14:00		

GPS UNIT# ______

SLOPE ANTENNA MEASUREMENTS

Note: All measurements are to be made inside notch and bottom edge of ground plane antenna.

SESSION 1	SESSION 2	SESSION 3	SESSION 4
1.647 M	1.635 M	____ M	____ M
1.649 M	1.636 M	____ M	____ M
1.651 M	1.638 M	____ M	____ M
5.404 FT= ____ M	5.370 FT= ____ M	____ FT= ____ M	____ FT= ____ M
____ M Mean Slope Distance	____ M Mean Slope Distance	____ M Mean Slope Distance	____ M Mean Slope Distance
1.647 M	1.635 M	____ M	____ M
1.649 M	1.636 M	____ M	____ M
1.651 M	1.638 M	____ M	____ M
5.404 FT= ____ M	5.370 FT= ____ M	____ FT= ____ M	____ FT= ____ M
____ M Mean Slope Distance	____ M Mean Slope Distance	____ M Mean Slope Distance	____ M Mean Slope Distance

E TRUE VERTICAL HEIGHT FORMULA = $\sqrt{(Mean\ SD)^2 - (0.2334)^2} + 0.0069$

____ M Vertical Antenna Height	____ M Vertical Antenna Height	____ M Vertical Antenna Height	____ M Vertical Antenna Height

JOHN CHANCE LAND SURVEYS, INC.
FLI-MAP GPS DATA SHEET
CORRIDOR MAPPING

CLIENT / PROJECT AREA: Grand Canyon Monitoring and Research

Observer: FARON O. Wk/Day: SUNDAY Date: 25-MAY-03 Job ____

	SESSION 1	SESSION 2	SESSION 3	SESSION 4
Station ID:	SCTH	SCTH		
Julian Date:				
Local Start Time:	09:40	12:11		
Survey Time:				
Local Stop Time:	12:00	14:00		

GPS UNIT# 5

SLOPE ANTENNA MEASUREMENTS

Note: All measurements are to be made inside notch and bottom edge of ground plane antenna.

SESSION 1	SESSION 2	SESSION 3	SESSION 4
1.648 M	1.642 M	____ M	____ M
1.648 M	1.642 M	____ M	____ M
1.649 M	1.643 M	____ M	____ M
5.406 FT= 1.648 M	5.388 FT= 1.642 M	____ FT= ____ M	____ FT= ____ M
1.648 M Mean Slope Distance	1.642 M Mean Slope Distance	____ M Mean Slope Distance	____ M Mean Slope Distance
1.648 M	____ M	____ M	____ M
1.649 M	____ M	____ M	____ M
1.648 M	____ M	____ M	____ M
5.406 FT= 1.648 M	____ FT= ____ M	____ FT= ____ M	____ FT= ____ M
1.648 M Mean Slope Distance	____ M Mean Slope Distance	____ M Mean Slope Distance	____ M Mean Slope Distance

TRUE VERTICAL HEIGHT FORMULA = $\sqrt{(Mean\ SD)^2 - (0.2334)^2} + 0.0069$

SESSION 1	SESSION 2	SESSION 3	SESSION 4
____ M Vertical Antenna Height	____ M Vertical Antenna Height	____ M Vertical Antenna Height	____ M Vertical Antenna Height

JOHN CHANCE LAND SURVEYS, INC.
FLI-MAP GPS DATA SHEET
CORRIDOR MAPPING

CLIENT / PROJECT AREA: **St. Louis COE/Grand Canyon, AZ**

Observer: Terry R. Wk/Day: **Sunday** Date: **25-MAY-03** Job **03-6027**

	SESSION 1	SESSION 2	SESSION 3	SESSION 4
Station ID:	DSVW	DSVW		
Julian Date:	145	145	145	
Local Start Time:	10:00 17:02 UTC	12:05 19:08 UTC	CALL	
Survey Time:				
Local Stop Time:	12:00 19:02 UTC	14:00 21:00 UTC	CALL	

GPS UNIT#__________

SLOPE ANTENNA MEASUREMENTS

Note: All measurements are to be made inside notch and bottom edge of ground plane antenna.

SESSION 1	SESSION 2	SESSION 3	SESSION 4
1.561 M	1.5685 M	___ M	___ M
1.562 M	1.5695 M	___ M	___ M
1.562 M	1.568 M	___ M	___ M
5.123 FT= 1.561 M	5.145 FT= 1.568 M	___ FT= ___ M	___ FT= ___ M
1.562 M Mean Slope Distance	1.569 M Mean Slope Distance	___ M Mean Slope Distance	___ M Mean Slope Distance
1.561 M	1.5685 M	___ M	___ M
1.562 M	1.5695 M	___ M	___ M
1.562 M	1.568 M	___ M	___ M
5.123 FT= 1.561 M	5.145 FT= 1.568 M	___ FT= ___ M	___ FT= ___ M
1.562 M Mean Slope Distance	1.569 M Mean Slope Distance	___ M Mean Slope Distance	___ M Mean Slope Distance

THE TRUE VERTICAL HEIGHT FORMULA = $\sqrt{(Mean\ SD)^2 - (0.2334)^2} + 0.0069$

___ M Vertical Antenna Height	___ M Vertical Antenna Height	___ M Vertical Antenna Height	___ M Vertical Antenna Height

JOHN CHANCE LAND SURVEYS, INC.
FLI-MAP GPS DATA SHEET
CORRIDOR MAPPING

CLIENT / PROJECT AREA: St. Louis COE/Grand Canyon, AZ

Observer: Connie L. Wk/Day: Sunday Date: 25-MAY-03 Job 03-6027

	SESSION 1	SESSION 2	SESSION 3	SESSION 4
Station ID:	EMIN	EMIN		
Julian Date:	145	145	145	
Local Start Time:	09.58 ~~10:00~~	12.03 ~~12:05~~	CALL	
Survey Time:	2:02 | 0.05			
Local Stop Time:	12:00	14:00	CALL	

GPS UNIT#

SLOPE ANTENNA MEASUREMENTS

Note: All measurements are to be made inside notch and bottom edge of ground plane antenna.

SESSION 1	SESSION 2	SESSION 3	SESSION 4
1.516 M	1.368 M	M	M
1.515 M	1.3695 M	M	M
1.515 M	1.369 M	M	M
4.964 FT= 1.513 M	4.497 FT= 1.371 M	FT= M	FT= M
1.515 M	1.369 M	M	M
Mean Slope Distance	Mean Slope Distance	Mean Slope Distance	Mean Slope Distance
1.515 M	M	M	M
1.516 M	M	M	M
1.514 M	M	M	M
4.970 FT= 1.515 M	FT= M	FT= M	FT= M
1.515 M	M	M	M
Mean Slope Distance	Mean Slope Distance	Mean Slope Distance	Mean Slope Distance

THE TRUE VERTICAL HEIGHT FORMULA = $\sqrt{(Mean\ SD)^2 - (0.2334)^2} + 0.0069$

1.504 M	1.356 M	M	M
Vertical Antenna Height	Vertical Antenna Height	Vertical Antenna Height	Vertical Antenna Height

JOHN CHANCE LAND SURVEYS, INC.
FLI-MAP GPS DATA SHEET
CORRIDOR MAPPING

CLIENT / PROJECT AREA: St. Louis COE/Grand Canyon, AZ

Observer: BLAINE T. Wk/Day: Sunday Date: 25-MAY-03 Job 03-6027

	SESSION 1	SESSION 2	SESSION 3	SESSION 4
Station ID:	L404	L404		
Julian Date:	145	145	145	
Local Start Time:	10:00	12:05	CALL	
Survey Time:				
Local Stop Time:	12:00	14:00	CALL	

GPS UNIT# 003

SLOPE ANTENNA MEASUREMENTS

Note: All measurements are to be made inside notch and bottom edge of ground plane antenna.

SESSION 1	SESSION 2	SESSION 3	SESSION 4
1.481 M	1.422 M	M	M
1.480 M	1.421 M	M	M
1.478 M	1.419 M	M	M
4.848 FT= 1.478 M	4.66 FT= 1.421 M	FT= M	FT= M
1.479 M Mean Slope Distance	1.421 M Mean Slope Distance	M Mean Slope Distance	M Mean Slope Distance
1.480 M	1.422 M	M	M
1.480 M	1.421 M	M	M
1.478 M	1.419 M	M	M
4.845 FT= 1.478 M	4.66 FT= 1.421 M	FT= M	FT= M
1.479 M Mean Slope Distance	1.421 M Mean Slope Distance	M Mean Slope Distance	M Mean Slope Distance

THE TRUE VERTICAL HEIGHT FORMULA = $\sqrt{(Mean\ SD)^2 - (0.2334)^2} + 0.0069$

1.468 M Vertical Antenna Height	1.408 M Vertical Antenna Height	M Vertical Antenna Height	M Vertical Antenna Height

09:45 ↓ 13:00 ↗ 13:10 ↓ 14:26

JOHN CHANCE LAND SURVEYS, INC.
FLI-MAP GPS DATA SHEET
CORRIDOR MAPPING

*10:06 HELICOPTER LIFTED FROM LANDING SITE
*11:40 HELICOPTER LANDED
*12:57 HELICOPTER LIFTED FROM LANDING SITE
HELICOPTER LANDED

CLIENT / PROJECT AREA: Grand Canyon Monitoring and Research

Observer: FARON O Wk/Day: MONDAY Date: 26-MAY-03 Job ________

	SESSION 1	SESSION 2	SESSION 3	SESSION 4
Station ID:	SCTH	SCTH		
Julian Date:	146	146		
Local Start Time:	~~09:45~~ 09:53	~~13:00 CALL~~ 12:38		
Survey Time:				
Local Stop Time:	~~CALL~~ 11:44	~~CALL~~ 14:30		

GPS UNIT# ________

SLOPE ANTENNA MEASUREMENTS

Note: All measurements are to be made inside notch and bottom edge of ground plane antenna.

SESSION 1	SESSION 2	SESSION 3	SESSION 4
1,509 M	1.500 M	M	M
1,509 M	1.500 M	M	M
1,507 M	1,503 M	M	M
4,949 FT= 1,508 M	4,931 FT= 1,503 M	FT= M	FT= M
1,508 M Mean Slope Distance	1,501 M Mean Slope Distance	M Mean Slope Distance	M Mean Slope Distance
1,509 M	1,500 M	M	M
1,509 M	1,502 M	M	M
1,507 M	1,503 M	M	M
4,949 FT= 1,508 M	4,930 FT= 1,503 M	FT= M	FT= M
1,508 M Mean Slope Distance	1,502 M Mean Slope Distance	M Mean Slope Distance	M Mean Slope Distance

TRUE VERTICAL HEIGHT FORMULA = $\sqrt{(Mean\ SD)^2 - (0.2334)^2} + 0.0069$

1,497 M Vertical Antenna Height	1,4905 M Vertical Antenna Height	M Vertical Antenna Height	M Vertical Antenna Height

* HELICOPTER FLEW BASE

JOHN CHANCE LAND SURVEYS, INC.
FLI-MAP GPS DATA SHEET
CORRIDOR MAPPING

CLIENT / PROJECT AREA: **St. Louis COE/Grand Canyon, AZ**

Observer: **CONNIE** Wk/Day: **MONDAY** Date: **26-May-03** Job #: **03-6027**

	SESSION 1	SESSION 2	SESSION 3	SESSION 4
Station ID:	EMIN	EMIN		
Julian Date:	146	146	146	146
Local Start Time: (UTC)	9:45 / 16:45	CALL /	/	/
Survey Time:				
Local Stop Time: (UTC)	13:00 / 20:00	CALL /	/	/

GPS UNIT# ____________

SLOPE ANTENNA MEASUREMENTS

Note: All measurements are to be made inside notch and bottom edge of ground plane antenna.

SESSION 1	SESSION 2	SESSION 3	SESSION 4
1.486 M	1.411 M	____ M	____ M
1.487 M	1.410 M	____ M	____ M
1.488 M	1.412 M	____ M	____ M
4.881 FT= 1.488 M	4.629 FT= 1.41 M	____ FT= ____ M	____ FT= ____ M
1.487 M Mean Slope Distance	1.411 M Mean Slope Distance	____ M Mean Slope Distance	____ M Mean Slope Distance
1.466 M	1.410 M	____ M	____ M
1.468 M	1.412 M	____ M	____ M
1.467 M	1.409 M	____ M	____ M
4.880 FT= 1.488 M	4.629 FT= 1.411 M	____ FT= ____ M	____ FT= ____ M
1.4875 M Mean Slope Distance	1.410 M Mean Slope Distance	____ M Mean Slope Distance	____ M Mean Slope Distance

THE TRUE VERTICAL HEIGHT FORMULA = $\sqrt{(Mean\ SD)^2 - (0.2334)^2} + 0.0069$

1.476 M Vertical Antenna Height	1.398 M Vertical Antenna Height	____ M Vertical Antenna Height	____ M Vertical Antenna Height

09:45 ↓ 13:00 ↗ 13:10 ↓ 14:26

JOHN CHANCE LAND SURVEYS, INC.
FLI-MAP GPS DATA SHEET
CORRIDOR MAPPING

CLIENT / PROJECT AREA: Grand Canyon Monitoring and Research

Observer: Chris G Wk/Day: Monday Date: 26-May-03 Job ______

	SESSION 1	SESSION 2	SESSION 3	SESSION 4
Station ID:	BCTH	BCTH		
Julian Date:	146	146		
Local Start Time:	09:45	12:25 ~~CALL~~		
Survey Time:				
Local Stop Time:	11:45 ~~CALL~~	14:35 ~~CALL~~		

GPS UNIT# ______

SLOPE ANTENNA MEASUREMENTS

Note: All measurements are to be made inside notch and bottom edge of ground plane antenna.

SESSION 1	SESSION 2	SESSION 3	SESSION 4
1.561 M	1.570 M	___ M	___ M
1.563 M	1.571 M	___ M	___ M
1.564 M	1.572 M	___ M	___ M
5.130 FT= 1.564 M	5.151 FT= 1.570 M	___ FT= ___ M	___ FT= ___ M
1.563 M Mean Slope Distance	1.571 M Mean Slope Distance	___ M Mean Slope Distance	___ M Mean Slope Distance
1.561 M	1.570 M	___ M	___ M
1.563 M	1.571 M	___ M	___ M
1.564 M	1.572 M	___ M	___ M
5.130 FT= 1.564 M	5.151 FT= 1.570 M	___ FT= ___ M	___ FT= ___ M
1.563 M Mean Slope Distance	1.571 M Mean Slope Distance	___ M Mean Slope Distance	___ M Mean Slope Distance

TRUE VERTICAL HEIGHT FORMULA = $\sqrt{(Mean\ SD)^2 - (0.2334)^2} + 0.0069$

1.552 M Vertical Antenna Height	1.560 M Vertical Antenna Height	___ M Vertical Antenna Height	___ M Vertical Antenna Height

JOHN CHANCE LAND SURVEYS, INC.
FLI-MAP GPS DATA SHEET
CORRIDOR MAPPING

CLIENT / PROJECT AREA: Grand Canyon Monitoring and Research

Observer: Chris Wk/Day: Tuesday Date: 05.27.03 Job ______

	SESSION 1	SESSION 2	SESSION 3	SESSION 4
Station ID:	BCTH	BCTH		
Julian Date:	147	147		
Local Start Time:				
Survey Time:				
Local Stop Time:				

GPS UNIT# #7

SLOPE ANTENNA MEASUREMENTS

Note: All measurements are to be made inside notch and bottom edge of ground plane antenna.

SESSION 1	SESSION 2	SESSION 3	SESSION 4
1.510 M	______ M	______ M	______ M
1.509 M	______ M	______ M	______ M
1.510 M	______ M	______ M	______ M
4.955 FT= 1.510 M	____ FT= ____ M	____ FT= ____ M	____ FT= ____ M
1.510 M Mean Slope Distance	______ M Mean Slope Distance	______ M Mean Slope Distance	______ M Mean Slope Distance
1.510 M	______ M	______ M	______ M
1.509 M	______ M	______ M	______ M
1.510 M	______ M	______ M	______ M
4.955 FT= 1.510 M	____ FT= ____ M	____ FT= ____ M	____ FT= ____ M
1.510 M Mean Slope Distance	______ M Mean Slope Distance	______ M Mean Slope Distance	______ M Mean Slope Distance

TRUE VERTICAL HEIGHT FORMULA = $\sqrt{(Mean\ SD)^2 - (0.2334)^2} + 0.0069$

SESSION 1	SESSION 2	SESSION 3	SESSION 4
1.499 M Vertical Antenna Height	______ M Vertical Antenna Height	______ M Vertical Antenna Height	______ M Vertical Antenna Height

JOHN CHANCE LAND SURVEYS, INC.
FLI-MAP GPS DATA SHEET
CORRIDOR MAPPING

* HELICOPTER LIFTED 11:00
X HELICOPTER Landed 12:28

CLIENT / PROJECT AREA: Grand Canyon Monitoring and Research

Observer: FARON O Wk/Day: TUESDAY Date: 27-MAY-03 Job ______

	SESSION 1	SESSION 2	SESSION 3	SESSION 4
Station ID:	SCTH	SCTH		
Julian Date:	147			
Local Start Time:	~~10:30~~ 09:41			
Survey Time:				
Local Stop Time:	12:28			

GPS UNIT# ______

SLOPE ANTENNA MEASUREMENTS

Note: All measurements are to be made inside notch and bottom edge of ground plane antenna.

SESSION 1	SESSION 2	SESSION 3	SESSION 4
1.587 M	___ M	___ M	___ M
1.587 M	___ M	___ M	___ M
1.586 M	___ M	___ M	___ M
5.205 FT= 1.586 M	___ FT= ___ M	___ FT= ___ M	___ FT= ___ M
1.5866 M	___ M	___ M	___ M
Mean Slope Distance	Mean Slope Distance	Mean Slope Distance	Mean Slope Distance
1.587 M	___ M	___ M	___ M
1.587 M	___ M	___ M	___ M
1.586 M	___ M	___ M	___ M
5.205 FT= 1.586 M	___ FT= ___ M	___ FT= ___ M	___ FT= ___ M
1.587 M	___ M	___ M	___ M
Mean Slope Distance	Mean Slope Distance	Mean Slope Distance	Mean Slope Distance

TRUE VERTICAL HEIGHT FORMULA = $\sqrt{(Mean\ SD)^2 - (0.2334)^2} + 0.0069$

SESSION 1	SESSION 2	SESSION 3	SESSION 4
1.576 M	___ M	___ M	___ M
Vertical Antenna Height	Vertical Antenna Height	Vertical Antenna Height	Vertical Antenna Height

JOHN CHANCE LAND SURVEYS, INC.
FLI-MAP GPS DATA SHEET
CORRIDOR MAPPING

CLIENT / PROJECT AREA: **St. Louis COE/Grand Canyon, AZ**

Observer: CONNIE Wk/Day: TUESDAY Date: 27-May-03 Job #: 03-6027

	SESSION 1	SESSION 2	SESSION 3	SESSION 4
Station ID:	EMIN	EMIN		
Julian Date:	147 ~~146~~	147 ~~146~~	147 ~~146~~	147 ~~146~~
Local Start Time:	10:42 ~~10:30~~ / 17:30 UTC	CALL / UTC	/ UTC	/ UTC
Survey Time:				
Local Stop Time:	12:30 / 19:30 UTC	CALL / UTC	/ UTC	/ UTC

GPS UNIT#__________

SLOPE ANTENNA MEASUREMENTS

Note: All measurements are to be made inside notch and bottom edge of ground plane antenna.

SESSION 1	SESSION 2	SESSION 3	SESSION 4
1.455 M	___ M	___ M	___ M
1.454 M	___ M	___ M	___ M
1.456 M	___ M	___ M	___ M
4.775 FT= 1.455 M	___ FT= ___ M	___ FT= ___ M	___ FT= ___ M
1.455 M Mean Slope Distance	___ M Mean Slope Distance	___ M Mean Slope Distance	___ M Mean Slope Distance
___ M	___ M	___ M	___ M
___ M	___ M	___ M	___ M
___ M	___ M	___ M	___ M
___ FT= ___ M	___ FT= ___ M	___ FT= ___ M	___ FT= ___ M
___ M Mean Slope Distance	___ M Mean Slope Distance	___ M Mean Slope Distance	___ M Mean Slope Distance

THE TRUE VERTICAL HEIGHT FORMULA = $\sqrt{(Mean\ SD)^2 - (0.2334)^2} + 0.0069$

1.443 M Vertical Antenna Height	___ M Vertical Antenna Height	___ M Vertical Antenna Height	___ M Vertical Antenna Height

5.5 FLIGHT LOG INFORMATION SHEETS

JOB NUMBER	03-6027	CLIENT	GCMAR
FLIGHT NUMBER	030526x1	TAIL NUMBER	N3895D

CREW

PILOT	Walter Wieser	OPERATOR	S Broussard
		OBSERVER	Morgan Reed

SYSTEM

	PRIMARY	SECONDARY	FRAME
S/N	5	4	4

SETTINGS

	PRIMARY	SECONDARY	ALTITUDE (m)	SPEED (m/s)
GAIN	0 1 2 3 (2 circled)	0 1 2 3 (1 circled)	100	16
THRESHOLD	0 1 2 3 (1 circled)	0 1 2 3 (2 circled)		
SCAN ANGLE	30 60 (60 circled)	30 60 (60 circled)		

STORAGE

	INS BOX	PRIMARY	MPEG-1	FIREWIRE 1X2
DISK#	DF 9	DF 7	HD 28	HD 30

		SECONDARY	MPEG-2
DISK#		DF 8	HD 29

TIME

	START	STOP
HOBBS (hrs)	22.2	24.8
SYSTEM (hrs)		
SURVEY (UTC)	17:07:34	18:41:20
VIDEO (UTC)	17:20:29	18:36:31
LASER (UTC)	17:23:24	18:36:16

WEATHER CONDITIONS

TEMP (F)	28°C 32.4°F
WIND (kts)	Calm
SKY	clear

REMARKS

PROJECT#			FLIGHT#	
LASER	START	STOP	START	STOP
BCTH 70	17:23:24	17:23:40		
	17:24:21	17:24:41		
BCTH 100	17:23:33	17:25:55		
	17:26:43	17:27:11		
SC1	17:33:38	17:39:09		
SC2 West of Center	17:42:37	17:49:32		
SC3	17:52:28	17:59:56		
SC4	18:02:58	18:08:59		
SC5 East of Center	18:10:43	18:17:08		
70M	18:17:23	18:25:51		
BCTH 70M	18:32:05	18:32:29		
	18:33:11	18:33:37		
BCTH 100M	18:34:27	18:34:52		
	18:35:56	18:36:16		
VIDEO	STOP	START	STOP	START

JOB NUMBER	03-6027	CLIENT	GLMAR
FLIGHT NUMBER	030526X#2	TAIL NUMBER	N3895D

CREW

PILOT	Walter Wisser	OPERATOR	S. Broussard
		OBSERVER	Morgan Reed

SYSTEM

	PRIMARY	SECONDARY	FRAME
S/N	5	4	4

SETTINGS

	PRIMARY	SECONDARY	ALTITUDE (m)	SPEED (m/s)
GAIN	0 1 2 3 (2 circled)	0 1 2 3 (1 circled)	100	18
THRESHOLD	0 1 2 3 (1 circled)	0 1 2 3 (2 circled)		
SCAN ANGLE	30 60 (60 circled)	30 60 (60 circled)		

STORAGE

	INS BOX	PRIMARY	MPEG 1	FIREWIRE 1&2
DISK#	DF 9	DF 7	HD 28	HD 30

		SECONDARY	MPEG 2
DISK#		DF 8	HD 29

TIME

	START	STOP
HOBBS (hrs)	24.8	27.1
SYSTEM (hrs)		
SURVEY (UTC)	19:58:34	21:28:07
VIDEO (UTC)	20:10:52	21:24:51
LASER (UTC)	20:12:05	21:23:07

WEATHER CONDITIONS

TEMP (F)	26°C
WIND (kts)	E-5-10
SKY	Clear

REMARKS

PROJECT #		FLIGHT #	

LASER	START	STOP	START	STOP
EMIN 70M	20:12:05	20:12:36		
	20:13:20	20:13:51		
EMIN 100M	20:14:26	20:15:10		
	20:16:24	20:17:05		
	20:18:13	20:18:42		
EM1	20:28:11	20:33:39		
EM2	20:36:39	20:42:11		
EM3	20:45:37	20:51:09	← ? GPS	
EM4	20:54:30	20:59:37		
EM5	21:02:49	21:07:56		
70M	21:09:53	21:14:12	← ? GPS	
EMIN 70M	21:19:08	21:19:25		
	21:20:11	21:20:48		
EMIN 100M	21:21:28	21:21:49		
	21:22:34	21:23:07		

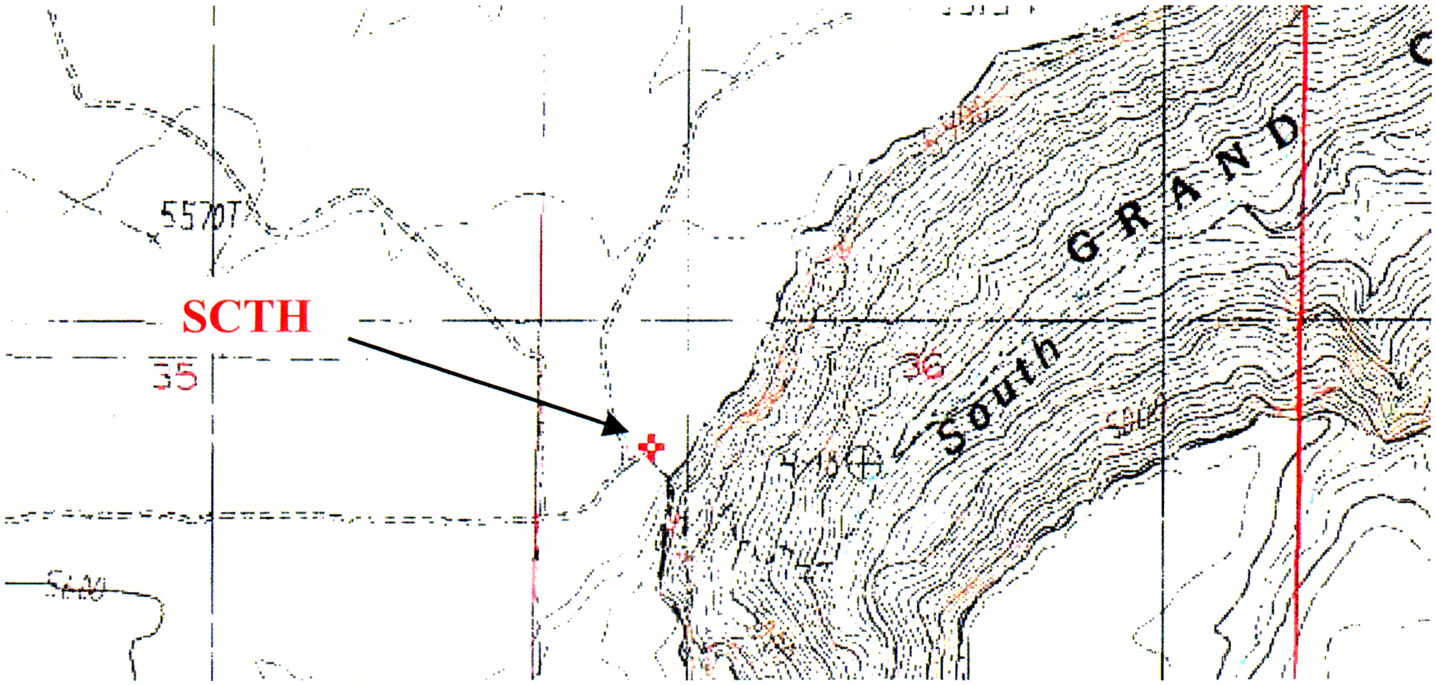
VIDEO	STOP	START	STOP	START

FLI-MAP
JOHN CHANCE LAND SURVEYS

JOB NUMBER	03-6027				CLIENT		St. Louis COE		
FLIGHT NUMBER	030527x1				TAIL NUMBER		N3895D		
CREW									
PILOT	Walter Wieser				OPERATOR		S. Broussard		
SYSTEM	PRIMARY		SECONDARY		OBSERVER		Mike Leshetski		
S/N	5		4		FRAME		4		
SETTINGS	PRIMARY		SECONDARY		ALTITUDE (m)		SPEED (m/s)		
GAIN	0 1 2 3 (2 circled)		0 1 2 3 (1 circled)		100		17		
THRESHOLD	0 1 2 3 (1 circled)		0 1 2 3 (2 circled)						
SCAN ANGLE	30 60 (60 circled)		30 60 (60 circled)						
STORAGE	INS BOX		PRIMARY		MPEG 1		FIREWIRE 1&2		
DISK#	DF 10		DF 1		HD 006		HD 008		
			SECONDARY		MPEG 2				
DISK#			DF 2		HD 007				
TIME	START				STOP				
HOBBS (hrs)	0027.1				30.0				
SYSTEM (hrs)									
SURVEY (UTC)	17:39:60				19:27:40				
VIDEO (UTC)	18:09:41				19:23:13				
LASER (UTC)	18:11:04				19:22:34				
WEATHER CONDITIONS									
TEMP (F)	32°C								
WIND (kts)	Light + Variable								
SKY	Clear								
REMARKS									

	PROJECT #		FLIGHT #	
LASER	START	STOP	START	STOP
EMIN 70M	18:11:04	18:11:27		
	18:12:07	18:12:31		
EMIN 100M	18:13:11	18:13:50		
	18:14:30	18:15:01		
EM1	18:20:31	18:25:11		
EM2	18:28:17	18:34:12		
EM3	18:37:10	18:43:15		
EM4	18:46:06	18:51:18		
EM5	18:54:28	19:00:30		
150M	19:03:26	19:07:44	P-G3T1	S-G2T2
	19:10:33	19:13:14	P-G3T1	S-G3T1
EMIN 70M	19:18:21	19:18:40		
	19:19:31	19:19:54		
EMIN 100M	19:20:45	19:21:17		
	19:22:05	19:22:34		
VIDEO	STOP	START	STOP	START

5.6 CONTROL DESCRIPTION SHEETS



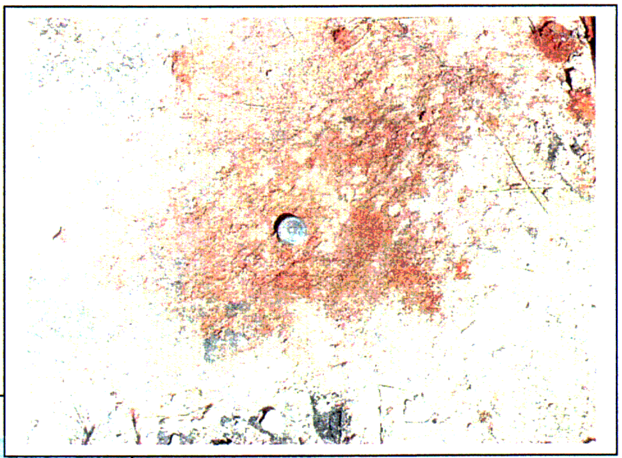
STATION NAME: " SCTH"
JCLS IDENTIFIER: " SCTH "

Monument Location: To reach "SCTH" from the Marble Canyon Lodge in Marble Canyon, AZ, travel westerly on Hwy 89A for approx 21.4 miles to a gravel road to the left leading to the House Rock Wildlife Area. Turn left and precede southerly on main road for approx. 18.9 miles to a gravel road on the left (632) leading to the Wildlife Area Headquarters. Turn left and precede ENE for approx. 1.9 miles to a gravel trail on the right leading to South Canyon Trail. Turn right and precede easterly for approx. 1.1 miles to a barbed wire gate. Pass through gate and precede straight approx. 0.1 miles to a parking area. The station is approx. 275 feet east of parking area on the second rim of the canyon. The station is a bolt with punch mark in the middle.

Monument Description: Bolt

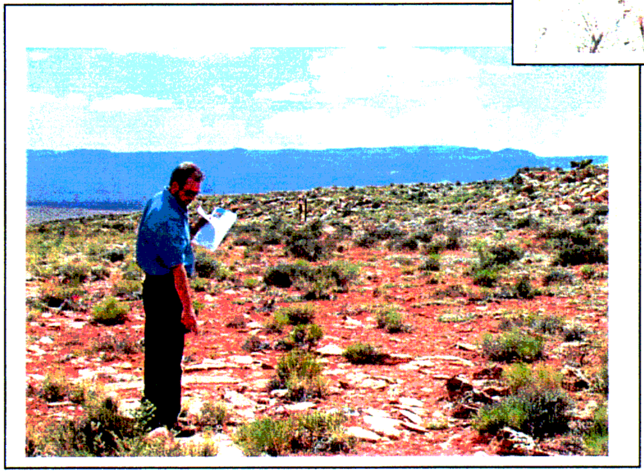
Date : May 2003

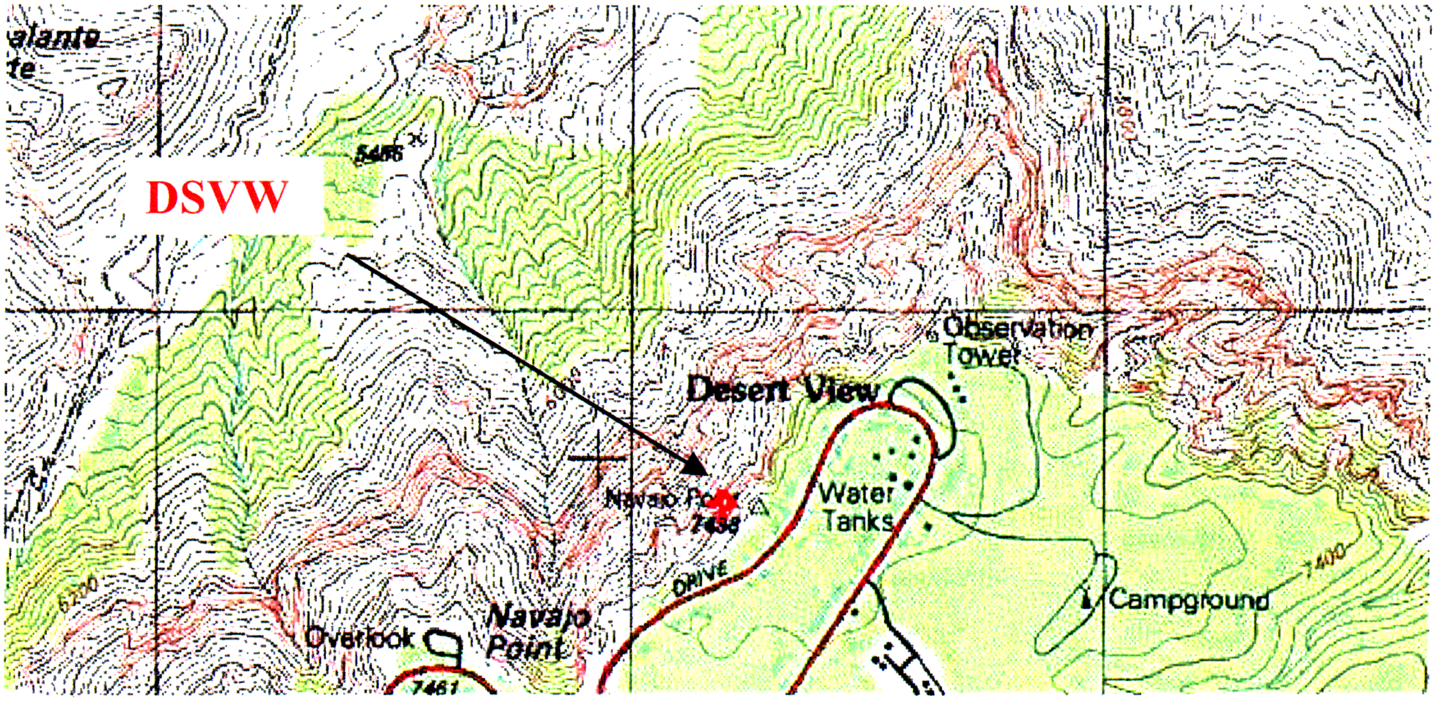
Monument Established By: Grand Canyon Monitoring & Research



Adjusted NAD 83 (2001 FBN Arizona) Geodetic Position
Lat. 36 28 26.68879 N
Long. 111 55 37.89581 W

Adjusted ELLIP Height(2001 FBN Arizona)
Elevation = 1676.303 m





STATION NAME: " DESERT VIEW"
PID: " AJ5640 "
JCLS IDENTIFIER: " DSVW "

Monument Location: To reach the station from Flagstaff, AZ drive north on US Hwy 89 to the town of Cameron. Turn west (left) on to State Hwy 64 and proceed for 33 miles to the entrance of the Grand Canyon National Park. Continue for 3.7 miles to a pullout on the right and park in the pullout. The pullout is also 0.6 miles beyond the fee station and 0.2 miles west of the west drive of the Desert View Parking lot. The pullout is also 1.7 miles northeasterly on Hwy 64 from the LIPAN View turnoff road. Once you park in the pullout, walk northerly toward the canyon rim for approximately 250 feet to the station. The station is set in top of a 5 inch X 5 inch X12 inch high concrete pedestal.

Monument Description: Brass disk stamped " DSVW GCMRC 01" "

Date : May 2003

Monument Established By: GRANCN

<u>Published NAD 83 (2001 FBN Arizona) Geodetic Position</u>
Lat. 36 02 26.77433 N
Long. 111 49 48.92330 W

<u>Published ELLIP Height (2001 FBN Arizona)</u>
Height = 2263.398 m

<u>Adjusted NAD 83 (2001 FBN Arizona) Geodetic Position</u>
Lat. 36 02 26.77433N
Long. 111 49 48.92330 W

<u>Adjusted ELLIP Height (2001 FBN Arizona)</u>
Elevation = 2263.407 m

National Geodetic Survey, Retrieval Date = JUNE 5, 2003
****

DESIGNATION -	**DESERT VIEW**	=	**"DSVW"**
PID -	AJ5640		
STATE/COUNTY-	AZ/COCONINO		
USGS QUAD -	DESERT VIEW (1988)		

*CURRENT SURVEY CONTROL

NAD 83(1992)-	36 02 26.77434(N)		111 49 48.92270(W)		ADJUSTED
NAVD 88 -	2286.6	(meters)	7502.	(feet)	GPS OBS

X -	-1,920,709.725	(meters)		COMP
Y -	-4,794,772.204	(meters)		COMP
Z -	3,733,182.314	(meters)		COMP
LAPLACE CORR-	3.01	(seconds)		DEFLEC99
ELLIP HEIGHT-	2263.38	(meters)	(10/04/01)	GPS OBS
GEOID HEIGHT-	-23.21	(meters)		GEOID99

HORZ ORDER - A
ELLP ORDER - THIRD CLASS II

The horizontal coordinates were established by GPS observations and adjusted by the National Geodetic Survey in October 2001.

The orthometric height was determined by GPS observations and a high-resolution geoid model.

Photographs are available for this station.

The X, Y, and Z were computed from the position and the ellipsoidal ht.

The Laplace correction was computed from DEFLEC99 derived deflections.

The ellipsoidal height was determined by GPS observations and is referenced to NAD 83.

The geoid height was determined by GEOID99.

	North	East	Units	Scale	Converg.
SPC AZ C -	559,039.778	221,146.287	MT	0.99990075	+0 03 03.0
UTM 12 -	3,988,789.369	425,208.696	MT	0.99966892	-0 29 18.6

U.S. NATIONAL GRID SPATIAL ADDRESS: 12SVE2520988789(NAD 83)
MARKER: DD = SURVEY DISK
SETTING: 7 = SET IN TOP OF CONCRETE MONUMENT
STAMPING: DSVW GCMRC 01
MAGNETIC: N = NO MAGNETIC MATERIAL
STABILITY: C = MAY HOLD, BUT OF TYPE COMMONLY SUBJECT TO
STABILITY: SURFACE MOTION
SATELLITE: THE SITE LOCATION WAS REPORTED AS SUITABLE FOR
SATELLITE: SATELLITE OBSERVATIONS - February 05, 2001

HISTORY	- Date	Condition	Report By
HISTORY	- 20010205	MONUMENTED	GRANCN
HISTORY	- 2003	GOOD	JCLS

STATION DESCRIPTION

DESCRIBED BY GRAND CANYON MONITORING AND RESEARCH 2001 (FMG)
THIS STATION IS A REPLACEMENT FOR NAVAJO POINT (GP0594) THAT WAS LOST TO VANDALISM EARLIER THIS YEAR. THE STATION IS LOCATED NEAR DESERT VIEW OVERLOOK (WATCH TOWER) ON SOUTH RIM DRIVE, HIGHWAY 64, GRAND CANYON, ARIZONA. THE STATION IS 34 MILES WEST OF CAMERON, AZ, 80 MILES NORTH OF FLAGSTAFF, AZ, AND 55 MILES NORTH OF WILLIAMS, AZ. THE STATION IS NEAR THE EASTERN EDGE OF GRAND CANYON NATIONAL PARK.

TO REACH THE STATION FROM FLAGSTAFF, AZ DRIVE NORTH ON US HIGHWAY 89 TO THE TOWN OF CAMERON. TURN WEST (LEFT) ON TO STATE HIGHWAY 64 AND PROCEED FOR 33 MILES TO THE ENTRANCE GRAND CANYON NATIONAL PARK. CONTINUE FOR 3.7 MILES TO A PULLOUT ON THE RIGHT (NORTH) AND PARK IN THE PULLOUT. THE PULLOUT IS ALSO 0.6 MILES BEYOND THE FEE STATION AND 0.2 MILES FROM WEST DRIVE OF DESERT VIEW PARKING LOT. WALK NORTHERLY TOWARD THE CANYON RIM FOR APPROXIMATELY 250 FT TO THE STATION.

THE STATION IS A 5 INCH X 5 INCH X 12 INCH HIGH CONCRETE PEDESTAL WITH A FLAT BRASS DISK IN THE CENTER APPROXIMATELY 25 FT FROM THE RIM OF THE CANYON. THE STATION DISK IS 2.5 INCHES IN DIAMETER, WITH STAMPINGS DSVW, GCMRC, AND 01.

National Geodetic Survey,   Retrieval Date = JUNE 5, 2003

****

DESIGNATION -	**EMIN**	=	**"EMIN"**	
PID -	AJ5639			
STATE/COUNTY-	AZ/COCONINO			
USGS QUAD -	TATAHATSO POINT (1988)			

*CURRENT SURVEY CONTROL

NAD 83(1992)-	36 24 12.03780(N)		111 49 51.09594(W)		ADJUSTED
NAVD 88 -	1765.4	(meters)	5792.	(feet)	GPS OBS

X -	-1,911,760.478	(meters)		COMP
Y -	-4,772,286.049	(meters)		COMP
Z -	3,765,341.401	(meters)		COMP
LAPLACE CORR-	2.19	(seconds)		DEFLEC99
ELLIP HEIGHT-	1742.55	(meters)	(10/04/01)	GPS OBS
GEOID HEIGHT-	-22.80	(meters)		GEOID99

HORZ ORDER - A
ELLP ORDER - THIRD   CLASS II

The horizontal coordinates were established by GPS observations and adjusted by the National Geodetic Survey in October 2001.

The orthometric height was determined by GPS observations and a high-resolution geoid model.

The X, Y, and Z were computed from the position and the ellipsoidal ht.

The Laplace correction was computed from DEFLEC99 derived deflections.

The ellipsoidal height was determined by GPS observations and is referenced to NAD 83.

The geoid height was determined by GEOID99.

	North	East	Units	Scale	Converg.
SPC AZ C -	599,267.974	221,056.290	MT	0.99990073	+0 03 03.3
UTM 12 -	4,029,007.280	425,498.962	MT	0.99966838	-0 29 35.2

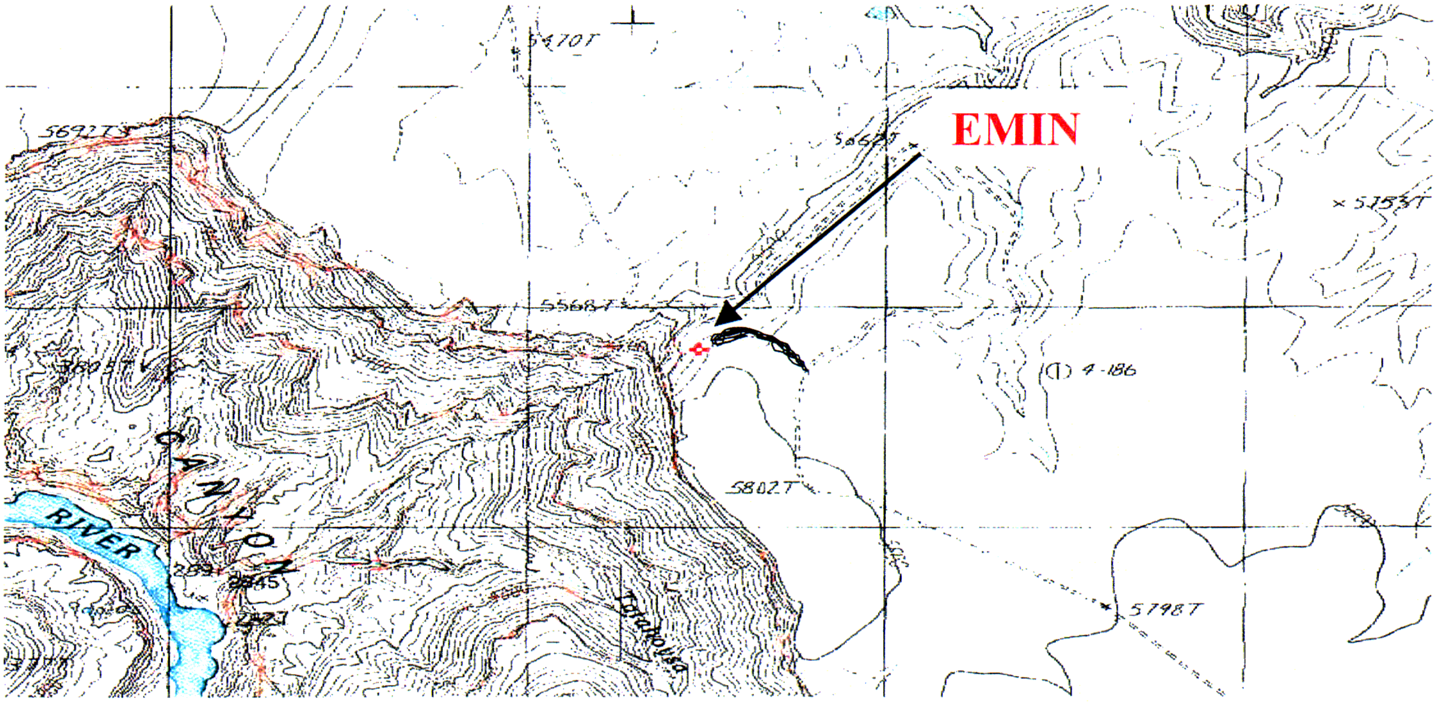
U.S. NATIONAL GRID SPATIAL ADDRESS: 12SVF2549929007(NAD 83)
MARKER: A = ALUMINUM MARKER
SETTING: 0 = UNSPECIFIED SETTING
STAMPING: EMIN GCMRC 01
MAGNETIC: I = MARKER IS A STEEL ROD
STABILITY: D = MARK OF QUESTIONABLE OR UNKNOWN STABILITY
SATELLITE: THE SITE LOCATION WAS REPORTED AS SUITABLE FOR
SATELLITE: SATELLITE OBSERVATIONS - April 26, 2001

HISTORY	- Date	Condition	Report By
HISTORY	- 20010205	MONUMENTED	GRANCN
HISTORY	- 20010426	SEE DESCRIPTION	GRANCN
HISTORY	- 2003	GOOD	JCLS

STATION DESCRIPTION

DESCRIBED BY GRAND CANYON MONITORING AND RESEARCH 2001 (FMG)
THE STATION IS LOCATED AT EMINENCE BREAK TRAILHEAD, 40 FT. DUE SOUTH OF A LARGE 4 FT CAIRN MARKING THE TRAILHEAD. TRAILHEAD IS APPROX. 500 FT SOUTHEAST OF LARGE NOTCH IN KAIBAB LIMESTONE DRAINAGE AND APPROX. 150 FT. HIGHER THAN ENTRANCE TO DRAINAGE. IT IS A 2.5 INCH ALUMINUM DISK ATTACHED TO A 24 INCH SECTION OF REBAR DRIVEN INTO THE GROUND (DUE TO THE DRIVING FORCE REQUIRED, IT IS EXPECTED THE REBAR IS WEDGED INTO A CRACK IN THE ROCK).

TO REACH FROM THE INTERSECTION OF STATE HIGHWAYS 89 AND 160, PROCEED NORTH ON 89 UNTIL JUST NORTH OF MILE MARKER 505. TURN WEST AT DIRT ROAD WITH LARGE 5 FT. MASONRY STONE STRUCTURE. STAY ON MAIN ROAD UNTIL YOU GET TO THE END OF BODAWAY MESA ON YOUR LEFT AND SHINUMO ALTER IN THE DISTANCE ON THE RIGHT. TURN RIGHT AT THE Y BEFORE THE GAP BETWEEN BODAWAY MESA AND TOOTH ROCK, CONTINUE WEST FOR APPROX. 0.5 MILE. TURN LEFT AFTER POND/TANK STRUCTURE ON LEFT. TURN LEFT AT Y AND CONTINUE PAST AN INTERSECTION AND ANOTHER TURNOUT ON LEFT. TURN LEFT AT Y TO PASS A HOGAN ON LEFT, CONTINUE STRAIGHT THROUGH AN INTERSECTION WHERE YOU COULD VEER LEFT. ROADS SPLIT AND PARALLEL EACH OTHER - TAKE EITHER ROAD. WHEN THESE ROADS COVERGE VEER RIGHT QUICKLY DROPPING DOWN A ROUGH HILL TO A POND/TANK. STAY TO THE LEFT OF THE TANK, ALWAYS WITHIN VIEW OF THE TANK. THE ROAD CONTINUES DIRECTLY ON THE WEST SIDE OF THE TANK AND IS LOSEST TO THE TANK. TURN LEFT AT NEXT Y AND STAY ON ROCKY ROAD. GO STRAIGHT AT NEXT Y, TURN RIGHT AT NEXT Y. CONTINUE NW ON THIS ROAD FOR A FEW MILES PARALLELING AND FINALLY IN VIEW OF THE NORTH RIM. CONTINUE UNTIL YOU GET TO A PILE OF GRAVEL AND A CHOLLA CACTUS. TURN LEFT AT THE GRAVEL PILE AND STAY LEFT UNTIL THE LARGE 4 FT. CAIRN IS IN VIEW.



STATION NAME: " EMIN"
PID: " AJ5639 "
JCLS IDENTIFIER: " EMIN "

Monument Location: The station is located on the Navajo Indian Reservation. From the small village of "The Gap" on Hwy 89 proceed north along Hwy 89 for 7.1 miles to entrance road on left just past mile marker 505. Entrance road is marked by large round rock structure that looks like a really big cairn. Turn left and proceed west for 6.8 miles along main road to west end of Bodaway Mesa and fork in main road (Shinumo Alter can be seen in the distance to the right). Take right fork and continue in a westerly direction along main road for 0.6 miles to a tank/pond structure on left and large metal tank on top of hill on your right. Veer left after tank/pond structure on left and proceed in a westerly direction for 0.9 miles to a fork in the road. Take the right fork and proceed westerly along rough road for 1.3 miles to another fork in the road. Take the left fork and follow the road for 0.7 miles to the next fork in the road. Take the left fork and proceed in a westerly direction for 3.0 miles past an Indian Hogan on the left to a tank/pond. Drop down a the rough hill, through the tank/pond and up the rough hill on the other side continue along the rough road for 2.2 miles to another fork in the road and a small cairn on the right. Take the right fork and follow the road westerly and then NW along the Canyon Rim for 3.6 miles to a dim fork to the left with a pile of gravel and a cholla cactus next to it. Turn left at this fork onto dim road and go 0.1 miles crossing over ridge (Canyon is now in clear view to the west). Turn left after crossing over ridge and proceed 0.1 miles to end of trail and station on the left.

Monument Description: Aluminum Marker stamped " EMIN GCMRC 01 "

Date : May 2003

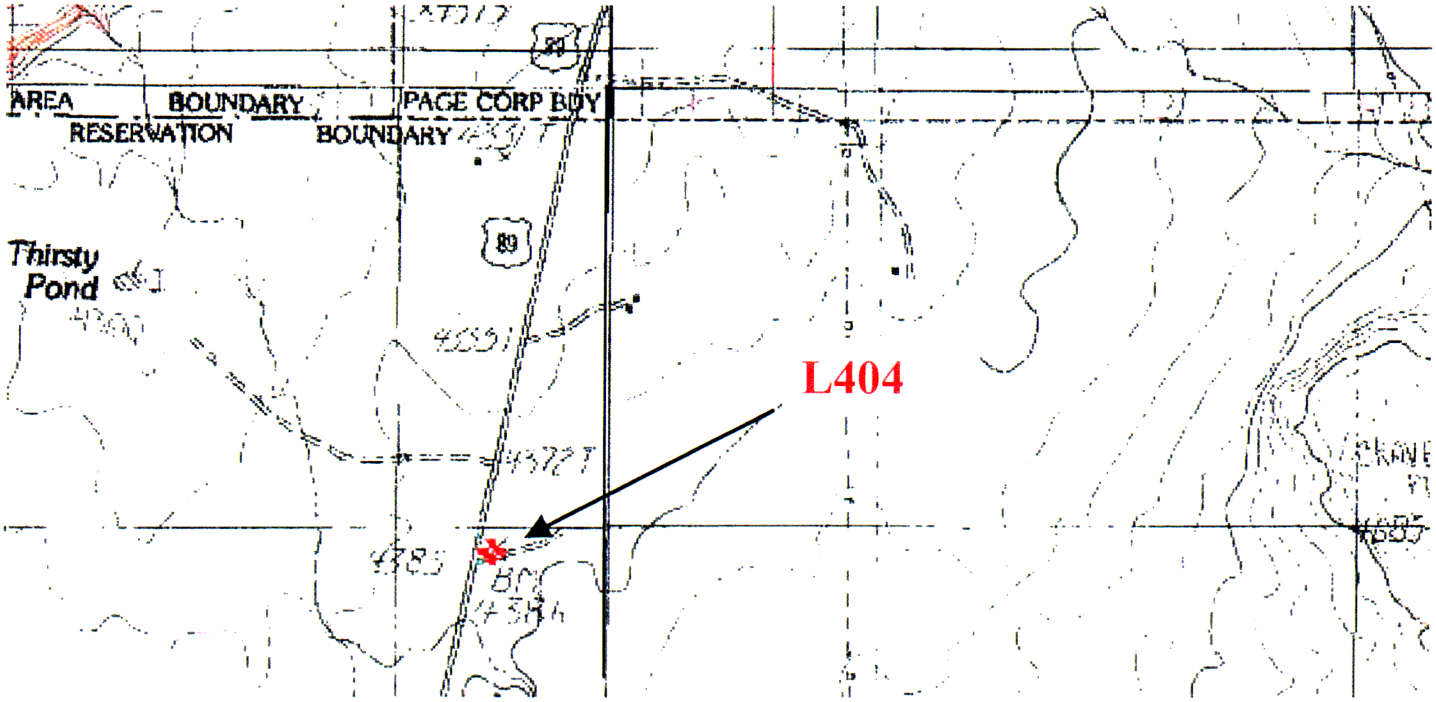
Monument Established By: GRANCN

Published NAD 83 (2001 FBN Arizona) Geodetic Position
Lat. 36 24 12.03777 N
Long. 111 49 51.09660 W

Published ELLIP Height (2001 FBN Arizona)
Height = 1742.567 m

Adjusted NAD 83 (2001 FBN Arizona) Geodetic Position
Lat. 36 24 12.03777 N
Long. 111 49 51.09660 W

Adjusted ELLIP Height (2001 FBN Arizona)
Elevation = 1742.567 m



STATION NAME: " L 404"
PID: " GP0283 "
JCLS IDENTIFIER: " L404 "

Monument Location: To reach the station from the intersection of Hwy 89 & Hwy 89A, south of the town of Page, AZ., proceed northerly on Hwy 89 for approximately 19.5 miles to a paved entrance and a fence on the right and the station on the easterly side of the fence. The station is also just north of mile marker 544.

Monument Description: Set in top of a concrete monument and stamped " L 404 1962"

Date : May 2003

Monument Established By: CGS

Published NAD 83 (2001 FBN Arizona) Geodetic Position
Lat. 36 51 58.31235 N
Long. 111 30 12.23455 W

Published ELLIP Height (2001 FBN Arizona)
Height = 1314.441 m

Adjusted NAD 83 (2001 FBN Arizona) Geodetic Position
Lat. 36 51 58.31235 N
Long. 111 30 12.23455 W

Adjusted ELLIP Height (2001 FBN Arizona)
Elevation = 1314.377 m

National Geodetic Survey,   Retrieval Date = JUNE 5, 2003
****

FBN -	This is a Federal Base Network Control Station.
DESIGNATION -	**L 404** = **"L404"**
PID -	GP0283
STATE/COUNTY-	AZ/COCONINO
USGS QUAD -	LEES FERRY (1985)

*CURRENT SURVEY CONTROL

NAD 83(1992)-	36 51 58.31254(N)		111 30 12.23396(W)			ADJUSTED
NAVD 88 -	1337.778	(meters)	4389.03	(feet)		ADJUSTED
X -	-1,873,091.194	(meters)				COMP
Y -	-4,754,292.058	(meters)				COMP
Z -	3,806,312.455	(meters)				COMP
LAPLACE CORR-	1.29	(seconds)				DEFLEC99
ELLIP HEIGHT-	1314.37	(meters)			(09/30/99)	GPS OBS
GEOID HEIGHT-	-23.41	(meters)				GEOID99
DYNAMIC HT -	1336.228	(meters)	4383.94	(feet)		COMP
MODELED GRAV-	979,426.7	(mgal)				NAVD 88

HORZ ORDER -	A	
VERT ORDER -	FIRST	CLASS II
ELLP ORDER -	THIRD	CLASS I

The horizontal coordinates were established by GPS observations and adjusted by the National Geodetic Survey in September 1992.

The orthometric height was determined by differential leveling and adjusted by the National Geodetic Survey in June 1991.

The X, Y, and Z were computed from the position and the ellipsoidal ht.

The Laplace correction was computed from DEFLEC99 derived deflections.

The ellipsoidal height was determined by GPS observations and is referenced to NAD 83.

The geoid height was determined by GEOID99.

The dynamic height is computed by dividing the NAVD 88 geopotential number by the normal gravity value computed on the Geodetic Reference System of 1980 (GRS 80) ellipsoid at 45 degrees latitude (g = 980.6199 gals.).

The modeled gravity was interpolated from observed gravity values.

	North	East	Units	Scale	Converg.
SPC AZ C -	650,702.437	250,206.468	MT	0.99991672	+0 14 52.6
UTM 12 -	4,080,147.696	455,131.073	MT	0.99962480	-0 18 07.3

SUPERSEDED SURVEY CONTROL

NAD 83(1992)-	36 51 58.31358(N)	111 30 12.23214(W)	AD(	) B
ELLIP HT -	1314.42 (m)	(09/30/92)	GP(	) 2 1

Superseded values are not recommended for survey control. NGS no longer adjusts projects to the NAD 27 or NGVD 29 datums. See file dsdata.txt to determine how the superseded data were derived.

U.S. NATIONAL GRID SPATIAL ADDRESS: 12SVF5513180148(NAD 83)
MARKER: DB = BENCH MARK DISK
SETTING: 7 = SET IN TOP OF CONCRETE MONUMENT
STAMPING: L 404 1962
MARK LOGO: NONE
MAGNETIC: N = NO MAGNETIC MATERIAL
STABILITY: C = MAY HOLD, BUT OF TYPE COMMONLY SUBJECT TO
STABILITY: SURFACE MOTION
SATELLITE: THE SITE LOCATION WAS REPORTED AS SUITABLE FOR
SATELLITE: SATELLITE OBSERVATIONS - June 07, 1999

HISTORY	- Date	Condition	Report By
HISTORY	- 1962	MONUMENTED	CGS
HISTORY	- 1983	GOOD	NGS
HISTORY	- 19920203	GOOD	NGS
HISTORY	- 19951211	GOOD	CHANCE
HISTORY	- 19981119	GOOD	NGS
HISTORY	- 19981119	GOOD	NGS
HISTORY	- 19990426	GOOD	NGS
HISTORY	- 19990607	GOOD	NGS
HISTORY	- 2003	GOOD	JCLS

STATION DESCRIPTION

DESCRIBED BY COAST AND GEODETIC SURVEY 1962
5.75 MI S FROM PAGE.
ABOUT 5.75 MILES SOUTH ALONG U.S. HIGHWAY 89 FROM THE NORTHEAST END OF THE GLEN CANYON BRIDGE AT PAGE, ARIZONA. 239 FEET NORTHEAST OF HIGHWAY MILEPOST NUMBER 544, 125 FEET EAST OF THE CENTERLINE OF THE HIGHWAY, 20 FEET NORTH-NORTHWEST OF THE CENTERLINE OF A PRIVATE TRACK ROAD, 2.0 FEET EAST OF A METAL WITNESS POST, ABOUT 3 1/2 FEET ABOVE THE LEVEL OF THE HIGHWAY, AND SET IN THE TOP OF A CONCRETE POST PROJECTING 6 INCHES.

STATION RECOVERY (1983)

RECOVERY NOTE BY NATIONAL GEODETIC SURVEY 1983
RECOVERED IN GOOD CONDITION. ADD--6.5 METERS (21.5 FT) EAST OF THE RIGHT OF WAY FENCE.

STATION RECOVERY (1992)

RECOVERY NOTE BY NATIONAL GEODETIC SURVEY 1992
THE STATION IS LOCATED ABOUT 9.3 KM (5.8 MI) SOUTH OF THE GLEN CANYON BRIDGE LOCATED AT PAGE, 6.1 KM (3.8 MI) SOUTH OF THE JUNCTION OF U.S. HIGHWAY 89L LEADING EAST AND U.S. HIGHWAY 89 LEADING SOUTH NEAR THE SOUTHWEST EDGE OF PAGE, AT MILE POST 544, AND AT THE EAST SIDE OF THE EAST RIGHT-OF-WAY FENCE OF THE HIGHWAY. OWNERSHIP--PRESUMED TO BE THE NAVAJO NATION.

TO REACH THE STATION FROM THE NORTHEAST END OF THE GLEN CANYON BRIDGE LOCATED NEAR THE NORTHWEST EDGE OF PAGE, GO SOUTH ON HIGHWAY 89 FOR 9.3 KM (5.8 MI) TO MILE POST 544, THE STATION ON THE LEFT AND A NAVAJO INDIAN RESERVATION MARKER ON THE RIGHT. THE STATION IS A STANDARD DISK SET IN THE TOP OF A CONCRETE POST PROJECTING 7 CM ABOVE THE GROUND. LOCATED 73.0 M (239.5 FT) NORTHEAST OF MILE POST 544, 38.0 M (124.7 FT) EAST OF THE CENTERLINE OF THE HIGHWAY, 6.5 M (21.3 FT) EAST OF RIGHT-OF-WAY FENCELINE, 6.5 M (21.3 FT) EAST OF A FIBERGLASS WITNESS POST, 6 M (19.7 FT) NORTHEAST OF THE CENTER OF A DIM TRACK ROAD AND 0.91 M (2.99 FT) ABOVE THE LEVEL OF THE HIGHWAY.

STATION RECOVERY (1995)

RECOVERY NOTE BY JE CHANCE AND ASSOCIATES 1995 (MFY)
RECOVERED AS DESCRIBED AND IN GOOD CONDITION THE WITNESS POST HAS BEEN MOVED IN LINE WITH FENCELINE

STATION RECOVERY (1998)

RECOVERY NOTE BY NATIONAL GEODETIC SURVEY 1998 (CSM)
RECOVERED AS DESCRIBED. LOCATED 0.08 KM (0.05 MI) NORTHWEST OF US HIGHWAY 89 MILEPOST 544.

STATION RECOVERY (1998)

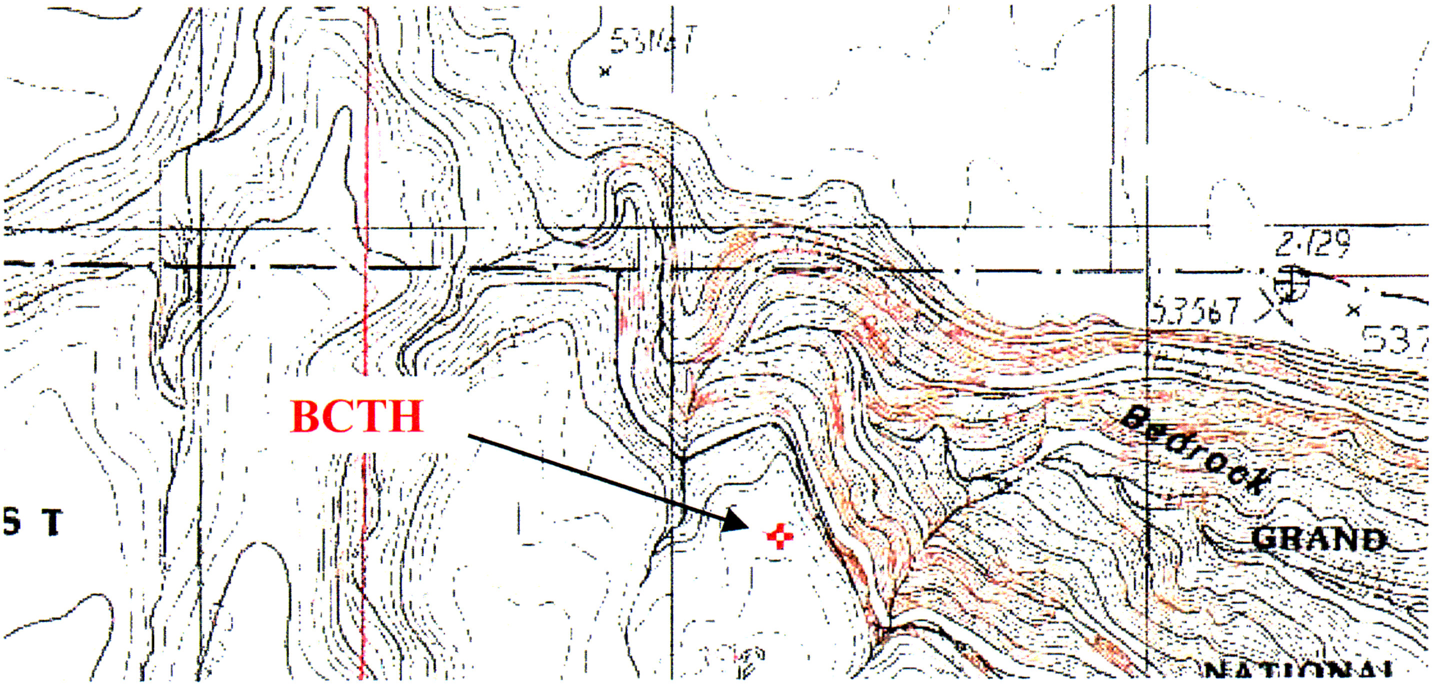
RECOVERY NOTE BY NATIONAL GEODETIC SURVEY 1998
RECOVERED IN GOOD CONDITION.

STATION RECOVERY (1999)

RECOVERY NOTE BY NATIONAL GEODETIC SURVEY 1999 (CSM)
RECOVERED AS DESCRIBED.

STATION RECOVERY (1999)

RECOVERY NOTE BY NATIONAL GEODETIC SURVEY 1999 (CSM)
RECOVERED AS DESCRIBED.



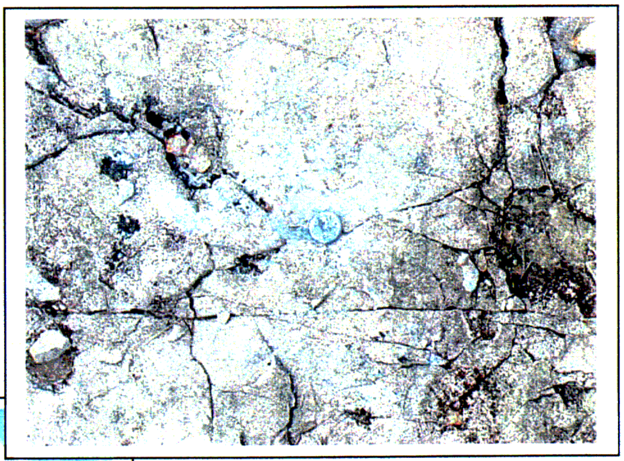
STATION NAME: " BCTH"
JCLS IDENTIFIER: " BCTH "

Monument Location: To reach "BCTH" from the Marble Canyon Lodge in Marble Canyon, AZ, travel westerly on Hwy 89A for approx 21.4 miles to a gravel road to the left leading to the House Rock Wildlife Area. Turn left and precede southerly on main road for approx. 18.9 miles to a gravel road on the left (632) leading to the Wildlife Area Headquarters. Turn left and precede ENE for approx. 1.9 miles to a gravel trail on the right leading to South Canyon Trail. Turn right and precede easterly for approx. 1.1 miles to a barbed wire gate. Pass through gate and take an immediate left on dirt trail and proceed along fence for approx. 0.2 miles to a y-intersection, bear right for an additional 2.8 miles to the end of the trail and the station straight ahead on the Bedrock Canyon rim. The station is a pk-nail set in a boulder.

Monument Description: PK Nail

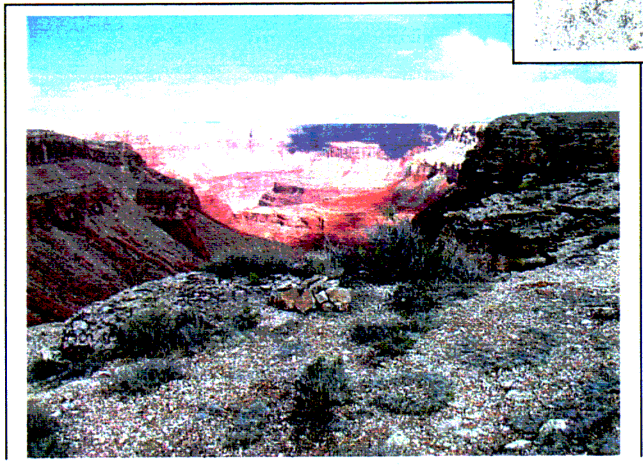
Date : May 2003

Monument Established By: JCLS



Adjusted NAD 83 (2001 FBN Arizona) Geodetic Position
Lat. 36 30 24.58059 N
Long. 111 54 06.58988 W

Adjusted ELLIP Height (2001 FBN Arizona)
Elevation = 1611.524 m



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 National Geodetic Survey,   Retrieval Date = JUNE  5, 2003
 *****************************************************************
 CORS           -  This is a GPS Continuously Operating Reference Station.
 DESIGNATION -  FREDONIA CORS L1 PHASE CENTER   =      "FRED"
 CORS_ID        -  FRED
 PID            -  AI8806
 STATE/COUNTY-  AZ/COCONINO
 USGS QUAD    -  SHINARUMP POINT (1988)

                          *CURRENT SURVEY CONTROL
 ____________________________________________________________________
 NAD 83(CORS)-  36 59 17.97783(N)     112 29 57.13531(W)     ADJUSTED
 NAVD 88      -
 ____________________________________________________________________
 EPOCH DATE   -        2002.00
 X            -  -1,952,383.614  (meters)                       COMP
 Y            -  -4,713,656.162  (meters)                       COMP
 Z            -   3,817,279.491  (meters)                       COMP
 ELLIP HEIGHT-          1530.75   (meters)         (03/??/02)  GPS OBS
 GEOID HEIGHT-           -22.11   (meters)                      GEOID99

 HORZ ORDER  -  SPECIAL (CORS)
 ELLP ORDER  -  SPECIAL (CORS)
```

ITRF positions are available for this station. The coordinates were established by GPS observations and adjusted by the National Geodetic Survey in March 2002. The coordinates are valid at the epoch date displayed above. The epoch date for horizontal control is a decimal equivalence of Year/Month/Day.

The PID for the CORS ARP is AI8805.

The XYZ, and position/ellipsoidal ht. are equivalent.

The ellipsoidal height was determined by GPS observations and is referenced to NAD 83.

The geoid height was determined by GEOID99.

```
                      North         East      Units   Scale      Converg.
SPC AZ C      -    664,333.413   161,504.367    MT  0.99993312 -0 21 01.8

                           SUPERSEDED SURVEY CONTROL

 NAD 83(CORS)-  36 59 17.97834(N)     112 29 57.13541(W) AD(1997.00) c
 ELLIP HT     -         1530.75  (m)           (09/??/01) GP(1997.00) c c
 NAD 83(CORS)-  36 59 17.98709(N)     112 29 57.13532(W) AD(1997.00) c
 ELLIP HT     -         1530.96  (m)           (12/??/00) GP(1997.00) c c
```

Superseded values are not recommended for survey control. NGS no longer adjusts projects to the NAD 27 or NGVD 29 datums. See file dsdata.txt to determine how the superseded data were derived.

U.S. NATIONAL GRID SPATIAL ADDRESS: 12SUF6658294628(NAD 83) MARKER: STATION IS THE L1 PHASE CENTER OF THE GPS ANTENNA

STATION DESCRIPTION

DESCRIBED BY NATIONAL GEODETIC SURVEY
STATION IS A GPS CORS. LATEST INFORMATION INCLUDING POSITIONS AND VELOCITIES ARE AVAILABLE IN THE COORDINATE AND LOG FILES ACCESSIBLE BY ANONYMOUS FTP OR THE WORLDWIDE WEB.

FTP CORS.NGS.NOAA.GOV: CORS/COORD AND CORS/STATION_LOG
HTTP://WWW.NGS.NOAA.GOV UNDER PRODUCTS AND SERVICES.

6.0 COPY OF SCOPE OF WORK

SCOPE OF WORK

Precision Airborne LIDAR Surveys
Grand Canyon Research & Monitoring Center
Erosion and Sedimentation sites
John Chance Land Surveys
Lafayette, LA
Contract No. DACW43-02-D-0505
Delivery Order No. 0007

1. Description of Work:

The Contractor shall collect digital elevation data from a precision airborne (LIDAR) survey along two projects in Northern Arizona for the Grand Canyon Monitoring & Research Center (GCMRC), USGS, in support of the erosion and sedimentation monitoring programs. The GCMRC requires very accurate digital terrain models (DTM's) to monitor erosion and sedimentation at 11 sites along the Colorado River in the Grand Canyon. This task order will test the technology on only two (2) sites. The approach will be to utilize portable FLI-MAP® technology and proprietary FLIP7® software to collect and process DTM data that will meet or exceed the GCMRC's specifications. The two project areas are (1) Eminence, and (2) South Canyon. It is ***not necessary*** to have the data orientation in the videos and Flip7 to be consistent for the surveys. The purpose of the surveys is to obtain a precise survey and develop a digital terrain model (DTM) of the projects to be surveyed for the purpose of determining volumes or obtaining other engineering data. The survey will be accomplished utilizing aerial topographic laser surveying techniques (LIDAR) to develop and identify all right of way characteristics and develop digital terrain models as necessary to obtain profiles of road crossings, piers, and other physical features

2. Information Supplied by the Government:

a. The Government will supply maps and coordinates of the two projects to be flown indicating all points of interest to be identified during the flight, and limits to be surveyed. The GCMRC has developed these maps:

- Site 1 Eminence 3.1 miles in length
- Site 2 South Canyon 2.8 miles in length

b. Section A containing Data Standards and Delivery requirements.

c. Section B containing minimum technical standards for GPS reference station occupations in the support of GCMRC control and remote sensing operations.

d. Section C containing special federal aviation regulation 50-2 and federal aviation regulation 93 subpart U, briefing for the Grand Canyon National Park Special Flight Rules Area.

3. Work to be Performed by the Contractor:

The Contractor shall provide equipment, supplies, aerial survey equipment and personnel, fully equipped to safely and expediently perform the following work:

a. A precision laser airborne mapping system, similar to FLI-MAP or better shall be used to acquire topographic point elevation data and high-resolution color digital video image data simultaneously along the two projects: The FLI-MAP or Fast Laser Imaging-Mapping and Profiling system integrates an accurate GPS positioning system with video imaging and two scanning reflectorless laser rangefinders to provide fast and accurate aerial surveys. The system, aboard a specially equipped Bell 206L helicopter or similar, is flown over the corridors of interest collecting precise GPS, platform altitude, laser ranges, and imagery data. With a data collection rate of 10,000 ranges per second per laser, height above ground of 100 meters (dependent upon vertical change of terrain and hills), and an aircraft velocity of 45 miles per hour, data density is approximately 10 or more per square meter. This data density makes it possible to differentiate planimetric features by recognizing patterns of points with spatial relationships.

b. The digital video image shall be recorded and digitized for correlation with the LIDAR data. Video shall be of highest quality and resolution available with the Fli-Map system. Digitized videos are required. An audio voice track shall also be included on the video with commentary to identify significant landmarks and aid in interpreting the laser images. The LIDAR scanning rate shall be approximately 16,000 points per second. Density of ground laser points shall be 10 per square meter or greater per laser. The flight altitude and speed shall be optimized to acquire the specified point density, resolution, and accuracy. The highest resolution, and absolute referenced elevation data is required. The airborne mapping system shall have an absolute accuracy of 15 centimeters horizontal and 10 centimeters vertical or better for LIDAR points.

The survey shall also include information to locate any structures, vegetation, and other shoreline features.

c. Basic horizontal control shall be established or recovered from the NGS database and be "B" order or better. A survey control plan shall be submitted to the U.S. Army Corps of Engineers (USACE) for approval by GRMRC before any field surveying is done. Any control points set shall be of a semi-permanent nature such as copperweld or re-bar type rods referenced for recovery by others. Once JCLS has mobilized to the project areas, local survey monumentation will be recovered to control the surveys and reference the FLI-MAP data to the desired horizontal coordinate system and vertical datum. (NAD 83/NAVD 88

Arizona State Plane Grid Coordinate System). Both vertical and horizontal survey control shall be in ***meters***. The number of recovered monuments will vary depending upon the measured relative accuracy of the existing monuments recovered. A dual frequency GPS receiver will be used at each site to record pseudo range and carrier phase information for subsequent on-the-fly (OTF) kinematic post processing.

d. It is necessary to have the projects flown after April 21, 2003 to assure vegetation is at a leaf-on condition. Close coordination for the flying dates must be maintained with the GCMRC, Flagstaff, AZ and/or the St. Louis District to insure the projects are flown during acceptable periods. Point of Contact with the GCMRC is Mr. Mike Liszewski , (928) 556-7458 or Mr. Phil Davis (928) 556-7133. Mr. Davis and Mr. Liszewski will be available during this time periods to assist in defining flight limits and boundaries in the field for all projects.

e. Data collection will be carefully planned to correspond with GPS windows of six or more satellites in view. Experience with continuous mass data collection has shown that careful tracking of the maximum number of GPS satellites is necessary to minimize data gaps or areas of less than acceptable data accuracy.

f. Flight operations will be coordinated with a client contact designated by GCMRC and JCLS ground support. Papillon Helicopters will provide a Bell 206 L-3 aircraft or equal from its Grand Canyon Village location. The pilot will maintain steerage by following pre-planned flight lines. Sufficient passes will be made over each project area to ensure adequate cover of laser data at an altitude of 100 meters above the base of the canyon. Flight operations require permitting from the National Park Service and the GCRMC will assist in the necessary coordination and a pre-flight meeting with the National Park Service is required.

g. Logged GPS pseudo range and carrier data, the INS data, and the laser data will be downloaded from the helicopter computer after the flight. This data and that from the reference GPS receivers will then be input to a central processing computer and the data quality is then field-verified.

4. <u>Methodology Specific to the Grand Canyon Project</u>

The ability of the FLI-MAP system to achieve its normal level of accuracy (15 centimeters horizontal and 15 centimeters vertical) will depend on achieving an accurate OTF kinematic post-processed solution of the GPS data. This requires that the FLI-MAP system on board the helicopter, and the base stations, be able to interrogate a minimum number of GPS satellites (minimum of 5, ideally at least 6) at all times. The base of the Grand Canyon provides a challenging location for GPS reception. In order for JCLS to ascertain the ability to achieve satisfactory GPS reception at the 2 individual test project locations, the following steps will be taken:

- Each project location will be accurately transferred to a topographical map. The topographical maps contain elevation data for the project site and surrounding terrain.
- Cross sections will be cut at each location in order to determine the slope angles of the canyon walls.
- Masks will be generated for each site, depicting the area of the sky that we estimate will be obscured by terrain at the helicopter's operating altitude.
- The masks will be been combined with known GPS satellite orbits to determine time windows when it is anticipated that sufficient GPS satellites will be visible to the FLI-MAP system at each location.

Data Processing

Due to data formats and processing algorithms, all of the data from each flight is pre-processed to produce three-dimensional positions of the laser returns. The GPS data from the base stations and the primary navigation receiver on the helicopter are reduced to produce vector offsets from all of the base stations to the helicopter. Least squares techniques are then utilized to determine a "best fit" three-dimensional position of the helicopter every one half second. The GPS data from the two on-board GPS receivers are also reduced kinematically to produce helicopter heading results every one half second. This position and attitude information is then time matched with the inertial and laser data to produce accurate XYZ's of the laser returns.

Accuracy of Captured Data

The absolute accuracy of discrete laser points (representing ground and feature data points) with FLI-MAP using OTF kinematic positioning is 0.5' (15 cm) horizontally and 0.5' (15 cm) vertically. The relative accuracy of data points collected with subsequent scans and to the kinematic control network is 0.35' horizontally and 0.25' vertically. The relative accuracy of points common to a single scan is 0.2'. The stated accuracies are to the 95% confidence level.

5. <u>Deliverables:</u>

   a. A survey narrative shall be produced in the form of a letter type report detailing all aspects of the LIDAR flight, including a description of the fieldwork and detailed office data processing procedures. The description shall include location, navigation and control, operations, all survey logs and data sheets used, any difficulties with the survey, and the method of resolution of the difficulties shall be documented. Two copies of the report for each of the two projects shall be provided.

   b. The contractor shall provide an interpretation and analysis of the results of the survey, including data quality, coverage of the area, and a summary of the findings. This summary shall be included in the transmittal letter documenting the electronic data delivered as a result of the survey. Two copies for each project shall be provided.

c. Fli-Map laser data will be delivered on DVD with the latest version of the FLIP-7 software. Upgrades to FLIP-7 software may be necessary for current users. Also, high-resolution color digital video imagery (360 x 240 pixels) that is time coded to the Fli-Map data will be delivered of the entire route in mpeg format. Three videos should be submitted including forward and down perspective with the third video being a digitized double zoom down video. Two copies of the Fli-Map laser data and digital video imagery shall be submitted on DVD. Additionally, two copies of ASCII data for the entire project shall be submitted on CD-ROM for use within other software that may not read the FLIP 7 compressed data format.

d. Two copies of two data sets are required. Both a cleaned and edited raw Fli-Map data set and a thinned to approximately 5% data set shall be delivered in ASCII format. The entire data set shall be filtered to produce a bare earth model and delivered in ASCII format. ASCII data file size shall be no greater than 200,000 points. Both a hard copy and digital index of the data file shall be produced.

e. The contractor will provide up to 24 hours of training for up to sixt (6) engineers or technicians or their representatives in the use of FLIP-7 software. The training will be conducted at the Contractors Office location. Transportation costs and per diem costs will be paid by Government personnel attending the training. Flip-7 technical support shall be provided for 24 hours of help (for each engineer or technician) by telephone over a one-year period. Responses to requests for technical support shall be made during normal business hours within 2 business days of initial inquiry. New releases or upgrades of the FLIP 7 software shall be provided to the St. Louis District of the U.S. Army Corps of Engineers and the GCMRC, Flagstaff, AZ at no cost of the Government for a period of one year.

f. A metadata file at least minimally compliant with the Federal Geographic Data Committee (FGDC) Content Standards for Digital Geospatial Metadata. The COE will provide a Metadata generation package (CORPSMET) to generate these files upon request by the Contractor or the Contractor can use software of their choice as long as the FGDC compliant Metadata is produced as specified in 2.b above.

JCLS will deliver 2 copies of the following information to GCMRC:

- 100% raw data XYZ ASCII File from the FLI-MAP Data.
- 100% cleaned bare earth XYZ ASCII File from the FLI-MAP Data.
- 100% processed all points.
- All raw Fli-Map project files.
- 5% thinned ASCII File (exact percentage coordinated with GCRMC).
- Digital Video delivered on DVD – Forward and Down Perspective

- Survey Control Report

JCLS will begin preparation of deliverables upon completion of data collection. A time estimate for delivery of the final product will be less than 20 business days (exception for FLIP7 training, which is to be defined by client) after completion of the flights.

5. Schedule and Submittal:

The contractor shall prepare and submit all deliverables and pertinent data, at no cost to the Government, to the U.S. ENGINEER DISTRICT, ST. LOUIS, CEMVS-ED-S (Attn: Robert D. Mesko), 1222 Spruce St., St. Louis, MO 63103-2833 before July 30, 2003.

6. Time Extension

In the event these schedules are exceeded due to causes beyond the control and without fault or negligence of the contractor, as determined by the Contracting Officer, this delivery order completion date will be extended one (1) calendar day for each day of delay.

Requests for time extensions for an individual task order should be forwarded to the Contracting Officer no later than fourteen (14) days preceding the completion date shown on the task order.